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Increasing Providers Awareness of Waste Anesthetic Gases Exposure in the Post-Anesthetic Care Unit: An Educational Module

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ABSTRACT

This quality improvement project aims to increase the providers' knowledge based on the current literature, the potential dangers of WAGs exposure, and ways providers can reduce exposure levels.

Background: The OR's concentration, effects, and reduction strategies are well addressed. Nevertheless, studies that address the exposure of WAGs in perioperative providers in the PACU are limited.

Methods: An in-depth inquiry was conducted using CINAHL, PubMed, and MEDLINE, to withdraw studies from 2014 to 2021 related to the PICOT question, of which eight articles were appraised. Then, an invitation of CRNAs solely to partake in a pre-test survey, followed by the educational module implementation and a post-test survey. Statistical analysis was applied to assess the impact of the educational intervention.

Results: There was a 60% increase in knowledge for the organization responsible for setting exposure limits to WAGs, also a 20% to 30% increase in the participant's ability to distinguish between the short- and long-term effects of WAGs exposure. Seventy percent of participants identified at-risk providers to WAG exposure. Finally, all participants knew that chronic WAGs had been linked to short- and long-term effects.

Discussion: There was increased knowledge regarding WAG exposure, adverse effects, and practices that reduce its exposure. Considering the limitations of the project and little research focused on mitigating WAGs exposure in the PACU, further research is needed. Limitations include the sample size of 10 participants and the virtual delivery of the educational module.

Keywords: PACU, perioperative providers, WAGs, adverse health effects, exposure.

INTRODUCTION

Advancement in technology and treatment approaches has given rise to a more complex healthcare system that is multifaceted, involving different specialties and disciplines. One of the specialties is anesthesiology. *Anesthesiology* is a highly stressful discipline that entails complex continuous monitoring, vast knowledge of pharmacology, and the ability to intervene during a rapid decline. This is related to the fact that anesthesia encompasses ensuring safety to and from the deliberate progression of loss of awareness, suppression of the autonomic nervous system, blunting nociception response and perception, and loss of sensation, in addition to the absence of recollection.[1-3] With such goals, anesthesia providers employ different techniques, such as total intravenous anesthesia, inhaled anesthetic agents, or a mixture of both.[3] The decision of what anesthetic technique is utilized depends on the patient's health record, the type of surgical procedure, and surgeon preference. The sedative effects are rapid onset and offset with whichever anesthetic technique is chosen. The inhaled anesthetic agents currently utilized in the United States (US) to achieve general anesthesia are volatile agents, including desflurane, isoflurane, sevoflurane, and nonvolatile agent nitrous oxide.[1,3]

Background

Since the 1800s, inhaled anesthetics have been a technique utilized. As the years progressed, improved and safer volatile agents were developed, and older agents were abandoned due to their toxic effects.[4] The inhaled anesthetic technique is utilized by an estimated 20 million people undergoing surgery in the US. During the administration of inhaled anesthetic gases and up to an hour after administration, small quantities of vapor and waste anesthetic gases (WAGS) leak from the patient breathing zone or apparatus into the environment because the anesthesia machine is not airtight.[2,5] WAGs are small amounts of volatile anesthetic gases that leak into the

environment; consequently, certain providers are exposed to these volatile agents while administering inhaled anesthetics in the operating room (OR) and post-anesthetic care unit (PACU).[2,4-6] Providers at-risk for exposure includes anesthesiologist, surgeons, nurse anesthetists, OR nurses, OR technicians, PACU nurses, and other PACU personnel.[6] The use of inhaled anesthetic agents poses an additional occupational risk for providers compared to other anesthetic techniques.[4] Exposure to WAGs cannot be eradicated as the anesthesia apparatus is not airtight. Post-extubation, patients still eliminate the vapors within their breathing zone; nevertheless, the goal is to limit or reduce exposure.[7] The National Institute for Occupational Safety and Health (NIOSH) set the exposure limit to WAGS in the US: nitrous oxide at 25 parts per million (ppm), halogenated agents at two ppm, and when used in combination with nitrous oxide at 0.5 ppm.[7]

Problem Identification

When patients arrive in the PACU, trace amounts of anesthetic waste gas are still released with each breath. Exposure to volatile anesthetics depends on the time the agents were continuously administered and the concentration of the agent in their breathing zone.[7] Breathing zone, as defined by the Occupational Safety and Health Administration (OSHA), is an area encompassing the face by approximately 6 to 9 inches.[8] Random measurement of WAGs samples in the PACU may show low levels; however, the breathing zones of the perioperative providers near the recovering patients may expose them to levels higher than the NIOSH set limits.[8] There is an increase of WAGs exposure in a setting where there are no scavenging systems or proper ventilation in the OR and in the PACU where the ventilation or scavenging system is not working correctly.[6] Current studies suggest that potential perioperative providers' exposure to

WAGs exceeds NIOSH limits, considering that such levels in the patient breathing zones surpass as much as 49% of the time.[8]

Chronic exposure to WAGs has been linked to both short-term and long-term effects. Short-term effects include nausea, drowsiness, headache, fatigue, irritability, and difficulties with judgment and coordination. While long-term effects include infertility, premature births, cancer, congenital abnormalities, spontaneous abortion, and renal and hepatic diseases.[5-10] Even with proper scavenging systems and air-conditioning, total elimination of WAGs is impossible.[10] The severity of the adverse health effects are directly related to the concentration of WAGs exposed to and the duration of time. For example, at-risk providers' exposure over 22 months was found to have an increased risk of DNA damage and oxidative stress compared to those exposed for 12 months.[10] This begs the research question are (P) perioperative providers (I) who are exposed to waste anesthetic gases in the PACU (C) compared to providers in a different specialty (O) at increased risk for adverse health effects (T) over four months?

Scope of the Problem

The risk of exposure is not limited to the OR. When the patient arrives at the PACU, measurable amounts of WAGs are exhaled, as inhaled anesthetics are primarily eliminated through the lungs, especially during the first recovery hour. The first hour of recovery is critical, requiring more vigilance and bedside attendance from perioperative providers, thus compiling the underrated period of increased exposure for perioperative providers.[7,11] Procedural areas such as the OR have implemented ways and techniques to reduce WAGs by scavenging and lessening the potential adverse health effects. However, a limited number of research studies address the risk of perioperative nurses' exposure in the PACU.[8] In the US, there is an estimated 528,197

perioperative nurses, so more than 250,000 are potentially exposed to WAGs. Females account for more than 78%, while males account for 15%.[5,12]

Consequences of the Problem

Although there is varying consensus in the literature about specific adverse health effects of WAGs exposure, multiple studies have documented increased exposure levels' consequences. Emara et al. conducted a study that evaluated the consequences of long-term exposure to WAGs on the immune system. Results showed elevated levels of IgE, IgM, and IgG. There is a correlation that WAGs can cause immunomodulation by causing changes in host leukocytic counts, lymphocyte activity, and ratios of lymphocyte subpopulations, possibly causing immune dysfunction.[13] In addition, short-term effects such as syncope, headache, dizziness, and fatigue were reported during working hours which can pose patient safety concerns, particularly when judgment is impaired.[13] WAGs have also been linked to hepatic alterations. Emara et al. measured hepatic biomarkers and showed increased plasma inorganic fluoride, HFIP, and liver toxicity markers.[2] Exposure to WAGs has also been linked with genotoxicity.[9]

Knowledge Gaps

Further research is needed to test the potential hazards in pregnant staff, as WAGs can induce genome instability and fetal neuronal damage.[14] The operating room has been typically connected to exposure to high concentrations of WAG. However, little is known about potential dangers related to continuous trace exposure in the PACU. Customarily, the PACU is not viewed as an area with an increased risk of exposure to WAG, which is why scavenging devices are not routinely used. However, recent studies demonstrate the possibility of surpassing NIOSH-recommended guidelines in the PACU.[11] The literature is limited when it comes to WAGs exposure in PACU.

Proposal Solution

Regarding WAGs exposure, the bulk of literature and techniques to mitigate its adverse effects and prolonged exposure focuses mainly on the OR environment. Increasing providers' knowledge of the problem and its effects is a good start when proposing any solution. Some studies have shown that in the breathing zone of the post-anesthesia patient, the level of WAGs eliminated is far greater than the set limits established by NIOSH.[8-9,11] Furthermore, a study by Boiano and Steege concluded that precautionary practices and recommendations were lacking among providers to varying degrees.[5] The proposed solution is an educational module detailing perioperative providers' risk of WAG exposure, thus creating steps to reduce exposure consciously. Williams et al. conducted a study to evaluate WAGs exposure and reduction using an ISO-Gard mask in the PACU. They found that the WAGs level was higher than two ppm for the one-hour evaluation period, and the mask effectively reduced the amount of exposure.[8]

SUMMARY OF LITERATURE REVIEW

Rationale/Objective

The OR's concentration, effects, and reduction strategies are well addressed. Nevertheless, studies that address WAGs' exposure to perioperative nurses in the PACU are limited. Additionally, the long-term effects of inhaled anesthetics agents are still inconclusive, especially in perioperative nurses. The literature review aims to examine the existing research on the adverse effects of WAGs exposure in perioperative nurses that work in the PACU and examine existing literature on the WAGs levels in the PACU compared to the limit set by the NIOSH.

Methodology/Eligibility Criteria

In order to solve the PICOT question, are (P) perioperative providers (I) who are exposed to waste anesthetic gases in the PACU (C) compared to providers in a different specialty (O) at increased risk for adverse health effects (T) over four months? A thorough analysis of the existing literature was done. The inquiry used search engines like MEDLINE, PubMed, and the Cumulative Index of Nursing and Allied Health Literature (CINHAL) to extract pertinent research findings. The catchphrases utilized in the inquiry incorporated a mix of 'waste anesthetic gases or volatile gases or inhaled anesthetics or volatile agents,' AND 'exposure,' AND 'side effects or adverse effects,' AND 'PACU or recovery unit,' and 'recovery nurses or postoperative nurse.' With the Underlying inquiry generating several studies, studies were excluded based on the pertinence related to the PICOT question, English as the language printed in, printed between the year 2014 to 2021, availability of an abstract, and full-text accessibility.

Following the inquiry restrictions to particular inclusion criteria, 229 studies were retrieved. Examining the studies' abstracts and titles resulted in 19 studies being included. Repeated studies were eliminated, lowering the number of articles to 15. Nevertheless, 7 studies were eliminated based on the need for the availability of the entire print. The remaining 8 articles were further appraised by reading the full text and chosen for this literature review. The findings were divided into common themes of adverse health effects and exposure levels in PACU.

Study Characteristics

Adverse Health Effects

Exposure to WAGs predisposes at-risk healthcare providers to short-term and long-term effects. Long-term adverse effects from WAGs are highly debatable. Current literature shows that exposure to WAGs long-term has led to infertility, congenital disabilities, miscarriages,

premature births, cancer, and liver and kidney diseases. While short-term adverse effects of WAGs exposure have been attributed to nausea, headache, drowsiness, and reduced work productivity due to fatigue, judgment, and coordination difficulties.[2,5,9]

Emara et al.[2] conducted a comparative cross-sectional study to identify variations in hepatic and hematological factors from prolonged WAGs exposure among vulnerable healthcare staff. The study was conducted between October 2018 and January 2019, and 180 participants were used, involving several healthcare facilities in Saudi Arabia in the Qassim region. Furthermore, the participants were allocated into control and exposed groups. The control group consisted of 60 healthy males who were never exposed to inhaled anesthetics vapors, and the other 120 participants were males working in areas with significant long-term exposure to WAGs, such as OR employees, including surgeons, surgical assistants (SA), anesthesiologists, anesthesiologist assistants (AA), nurses, and technicians.[2] The study subjects were instructed to fast overnight. A 10ml blood sample was collected in the morning between 0800 and 0900, which included the evaluation of complete blood counts (CBC), plasma fluoride and hexafluoroisopropanol (HFIP) levels, aspartate aminotransferase (AST), alanine aminotransferase (ALT), alkaline phosphatase (ALP) and serum osteopontin (OPN).[2] Results showed that compared to the control group, the plasma fluoride and HFIP concentrations were more significant in all exposed groups; however, levels were significantly increased in anesthesiologists and AAs in the exposed group. The CBC revealed a substantial drop in hemoglobin, hematocrit, platelets, red blood cells, mean corpuscular volume, mean corpuscular hemoglobin, and mean corpuscular hemoglobin concentration in the exposed group instead of the control group.[2] Furthermore, the exposed group's white blood cells, granulocytes, and lymphocytes were significantly high; however, monocyte levels decreased.[2]

Compared to the control group, the ALT and AST concentration analysis showed an elevation in all the exposed groups; ALT was specifically more elevated in the surgeons and AA samples. While the AST concentration was substantially increased in nurses, surgeons, AAs, and anesthesiologists.[2] ALP concentrations were higher in the blood sample collected from anesthesiologists, AA, and surgeons. Serum OPN was substantially elevated in the exposed group, specifically among AAs, surgeons, and anesthesiologists. Lastly, the serum albumin concentration was reduced in the exposed group.[2] The significance of the differences in the exposed and control groups was analyzed using a one-way ANOVA and a Dunnett test.[2] The research concluded that the hematopoietic system is sensitive to inhaled anesthetic agents' toxic effects, thus inciting anemia, based on the decreased parameters in the CBC analysis. Furthermore, reducing blood flow to the liver is correlated with inhaled anesthetic agents' toxic effects, producing toxic metabolites and altering liver markers.[2]

Another study examined the effect of WAGs exposure on the immune system. Emara et al.[13] aimed to analyze the consequences of long-term exposure in at-risk healthcare providers. The study was conducted over five months between October 2018 and January 2019 with a sample size of 180 subjects, including two groups consisting of 60 healthy males for the controlled group and 120 at-risk healthcare providers, further subdivided into their disciplines, i.e., AAs, surgeons, anesthetists, nurses, technicians, and SAs. A fasting 10 ml blood sample was collected into a silicon-coated tube between 0800 and 0900. Which included the evaluation of Immunoglobulins IgA, IgG, IgE, IgM, CD3, CD4, CD8, CD4/CD8 ratios, total lymphocyte counts, serum fluoride, and HFIP.[13] The differences and significant results were evaluated using one-way ANOVA and a Dunnett test. It showed that plasma fluoride and HFIP levels were increased in the exposed group compared to the control group, especially in the anesthetist and

AA group. The Serum IgE, IgM, IgG, and IgA in all the exposed groups were considerably elevated to varying degrees. SAs were the only subgroup sample that failed to reveal any substantial elevation in the IgE concentration. All the exposed subdivisions showed a significant elevation in total lymphocyte levels; however, CD3 concentration showed no significant change. A reduction in CD8 and significant elevation of CD4 and CD4/CD8 ratios were only in the anesthetists and AA group.[13] Emara et al. detailed a positive correlation between plasma fluoride levels with lymphocytic counts, percentage of CD4, CD4/CD8 ratios, serum IgE, IgG, and IgM, but not with IgA, CD8, and CD3. In the conclusion of the study, with the various increases and decreases noted, there is a possibility of immune dysfunction in healthcare workers exposed to WAGs.[13]

Lastly, Cakmak et al.[9] researched the genotoxicity risk of OR and PACU providers due to exposure to WAGs. The study sample size included 46 at-risk healthcare providers, 13 anesthetists, 13 OR nurses, 8 OR technicians who had contact with volatile agents such as nitrous oxide, sevoflurane, and desflurane, and 12 PACU nurses from the same hospital in Turkey. The study's control group consisted of 21 healthy providers from another specialty or unit that did not have a prior work history in the OR and PACU. Before sampling, a detailed questionnaire was also utilized, including demographic information, smoking history, alcohol intake, body mass index, and any recent diagnostic X-ray examination. Post-shift urine was retrieved to assess inorganic fluoride levels. Blood samples were collected, delivered to the laboratory on the same day, and processed within five hours of sampling for the micronucleus test to assess peripheral blood lymphocytes (PBLs). Also, buccal epithelial cells (BECs) were collected by utilizing a pre-moistened tongue depressor and scrubbing both sides of the inner cheeks, and the participants rinsed their mouths.[9]

Additionally, passive exposure samples were collected in the providers' breathing zone.[9] IBM SPSS version 17.0 software and ANOVA were used to analyze the data collected. The results showed that the OR air sevoflurane concentration in the three ORs measured was 0.32, 0.38, and 0.58 ppm, while the PACU level was 0.43 ppm.[9] Urine sevoflurane was not detected in the control group, while although detected in the OR and PACU, comparatively, the levels detected were similar. Urine sevoflurane levels surpassed the biological norm in 23 participants: 9 anesthetists, 5 nurses, 3 technicians, and 6 PACU. Compared to the control group, the micronucleus frequency in PBL was substantially increased, and a threefold increase in BECs in the exposed group, especially those exposed to sevoflurane, the principal inhaled anesthetic agent used in this research study. Hence, based on the micronucleus frequencies in PBL and BEC results, it reflects high chromosomal instability and genotoxicity.[9]

Exposure Levels in PACU

The NIOSH sets the exposure limit for WAGs in the US, but the OSHA enforces the exposure limit. Most of the literature published addresses the exposure levels in the OR. However, it is imperative to note that recommended levels apply anywhere inhaled anesthetics are utilized and in the PACU.[8] WAGs exposure concentration is dictated by the level of inhaled anesthetics in the breathing zone, and the time the gas is constantly inhaled.[8]

Five studies for the literature review evaluated the exposure levels in the PACU. Williams et al.[8] conducted a prospective observational study over four months to evaluate WAGs measurement in nurses' breathing zone emitting from patients who obtained volatile anesthetics during the first recovery hour in the PACU. The study included 125 patients booked for outpatient surgery with an inclusion criterion of greater than 18 years, duration of procedure greater than two hours, inhaled anesthetic agents as the primary form of sedation, and expected

to stay in the PACU for at least an hour.[8] In addition, 24 nurses were also recruited to participate. Aside from determining the number exhaled from the patients postoperatively, the authors' aim was also to examine the extent of PACU nurses' exposure. The participants' breathing zone's WAG levels were constantly assessed at thirty-second intervals for an hour. The result revealed that WAGs were more substantial than two ppm within the patient's breathing zone during the first recovery hour. Also noteworthy was that the number of WAGs measured in the PACU nurses' breathing zone was more significant than the NIOSH recommended limits, measuring at concentrations greater than two ppm during the same time frame.[8]

Similarly, Hiller et al.[15] conducted an observational study to measure sevoflurane WAG concentration in the PACU. They measured the breathing zone of a patient who only received sevoflurane, was extubated in the OR, and recovered in a PACU that met the engineering standards of NIOSH. Measurement was taken with a compact, calibrated Miran infrared spectrophotometer attached to a wand positioned 8 inches from the patient's mouth during the first hour of recovery. The results showed that exposure levels exceeded recommended limits for the PACU nurses during the times' the measurements were taken.[15]

Another prospective observational study by Herzog-Niescery et al.[16] from October 2017 to January 2016 in a German University hospital assessed PACU providers' exposure to sevoflurane during direct patient care by monitoring pre-and post-shift urinary sevoflurane levels. In addition, air pollution levels were measured in the PACU and hallways around the PACU. Pollution was measured at the height of 150 cm ten times within 9 hours, and the patient's breathing zone levels were calculated 25 times in one hour. For their result analysis, excel 2007 and IBM SPSS version 20 were utilized. The result showed measurable gas peaks and increased significantly from baseline during regular working hours. The highest sevoflurane

levels were measured 15 minutes after the patient's arrival. Compared to pre-shift sevoflurane urine levels, post-shift levels were considerably higher.[16] In contrast, Heiderich et al.[14] conducted a prospective observational study of WAGs concentrations in PACU. They assess levels of WAGs to room size, patient numbers, and ventilator settings. The study occurred in two different PACU in Germany for a week from 23 to 29 November 2016. Samples were taken in the center of the rooms at five-minute intervals using a compact ion mobility spectrometer.[14] The result showed low trace amounts of sevoflurane in 805 out of 970 samples, hence not exceeding the exposure limit.[14]

Lastly, McGlothlin et al.[11] conducted a descriptive and comparative study to evaluate and control WAGs in the PACU. The study included 19 patients with an inclusion criterion of healthy, age greater than 18, inhaled anesthetic agents were the primary form of sedation, and females had negative pregnancy tests. Samples were taken using a Miran wand at six inches over the patient's mouth and nose and three feet from the side of the patient mouth and nose to capture the breathing zone for about 50 minutes for every participant. After comparing the controls and cases in the case-control study to WAGs' exposure to PACU nurses using standard mean and standard deviation formulas. The result showed that exposure to nitrous was 2.9 times increased than that of nurses whose patient was utilizing an ISO-Gard mask at 6 inches. While at three feet, there was a 1.6 times increase.[11] The result was also similar for sevoflurane exposure; at both 6 inches and 3 feet, exposure levels were substantially elevated in exposed nurses compared to the control group.[11]

Author(s)	Purpose	Methodology/Research Design	Intervention(s) Measures	Sampling/Setting	Primary Results	Relevant Conclusion
Emara et al,[2] 2020	To identify liver and hematological parameters alterations occurring due to chronic exposure to WAG among vulnerable healthcare workers.	Comparative Cross-sectional study Level II	A cross-sectional comparative study was conducted in a Saudi Arabian hospital between October 2018 and January 2019 on operating room personnel vulnerable to WAG exposure.	Fasting blood samples were collected from 180 participants, with a control group of 60 and 120 exposed providers in numerous hospitals in the Qassim region of Saudi Arabia. Collected blood samples examined CBC, HFIP, AST, ALT, ALP, OPN, and plasma fluoride levels.	The exposed groups had significantly elevated plasma fluoride levels, HFIP levels, white blood cells, lymphocytes, granulocytes, and a significant reduction in hemoglobin, platelets, and hematocrit. Liver parameters in the exposed group, such as ALT, AST, ALP, and OPN, were substantially elevated.	The hematopoietic system is susceptible to inhaled anesthetic agents' toxic effects, thus inciting anemia, based on the decreased parameters in the CBC analysis. Furthermore, reduced blood flow to the liver is correlated with inhaled anesthetic agents' toxic effects, producing toxic metabolites and altering liver markers.
Emara et al,[13] 2021	To examine the consequences and effects of	Comparative Cross-sectional study Level II	A cross-sectional comparative study was conducted in a	Fasting blood samples were collected from a total of 180	The exposed group plasma fluoride, HFIP levels,	There was a positive correlation between plasma

	WAGs exposure long-term on the immune system.		hospital in Saudi Arabia over five months between October 2018 and January 2019.	participants, with a control group of 60 and 120 exposed at-risk providers in several hospitals in the Qassim region of Saudi Arabia. Collected blood samples examined Immunoglobulins IgA, IgG, IgE, IgM, CD3, CD4, CD8, CD4/CD8 ratios, total lymphocyte counts, serum fluoride, and HFIP.	Serum IgE, IgM, IgG, IgA, and lymphocytes significantly increased compared to the control group. There was a reduction in CD8 and a significant elevation of CD4 and CD4/CD8.	fluoride levels with lymphocytic counts, percentage of CD4, CD4/CD8 ratios, serum IgE, IgG, and IgM, but not with IgA, CD8, and CD3. As the conclusion of the study, there is a possibility of immune dysfunction in healthcare workers exposed to WAGs.
Cakmak et al,[9] 2019	To evaluate the genotoxicity risk of OR and PACU providers due to WAGs exposure.	Comparative Cross-sectional study Level II	The study was conducted in 3 ORs in Turkey's urologic and gastrointestinal surgical units. Detailed questionnaires included parameters such as age, gender,	The sample size included forty-six at-risk healthcare providers and 21 healthy non-exposed providers at Yuksek Ihtias Hospital. Post-shift urine was retrieved to assess inorganic	Air sevoflurane concentration levels in three ORs were 0.32, 0.58, and 0.38, while PACU was 0.43 ppm. Compared to	Based on the micronucleus frequencies in PBL and BEC results, it reflects high chromosomal instability and genotoxicity.

			and BMI before blood samples were retrieved.	fluoride levels, and blood samples were retrieved to assess PBLs and BECs. In addition, providers collected passive exposure samples in the breathing zone. IBM SPSS version 17.0 software and ANOVA were used to analyze the data collected.	the control group, urine sevoflurane exceeding biological levels was detected. Micronucleus frequency in PBL and BECs was substantially increased in the exposed group.	
William et al,[8] 2019	To evaluate the extent of WAGs in PACU and assess the efficacy of ISO-Gard masks in lowering exposure.	Prospective observational study Level II	Patients were randomly selected to receive the Gard mask limiting nurses' exposure or a standard oxygen delivery mask. Nonstop particulate levels were estimated using infrared spectrophotomete	The study included 125 patients scheduled for surgery and 24 nurses at Memorial Hermann Hospital in Texas. Each group was summarized into demographics, vital signs, adverse events, WAG levels, and laboratory	Fifty-six patients made up the traditional mask group 0, and 52 were in the ISO-Gard group 1. The median duration of MAX-WAG (greater than two ppm) within the	No adverse effects were noted related to the usage of the ISO-Gard mask. Within the patient's breathing zone, WAGs were more significant than two ppm during the first hour of

			rs placed inside the patients' and nurses' 6-inch breathing zones over four months.	variables. The minimum, average, maximum, and aggregate WAG levels in PACU between control groups and the study were evaluated using the Wilcoxon rank-sum test and two-sample t-test. Statistical evaluations were performed utilizing SAS 9.4.	patient breathing zone was 19.5 minutes in group 0 and 13.5 minutes in group 1. The median proportion of MAX-WAG for the collection period was 32.2% and 22.4 % in groups 0 and 1, respectively. Within the nurses' breathing zone, the median MAX-WAG was 1 minute in group 1 and 3 minutes in group 0. In contrast, the median proportion was 2% in	recovery. Additionally, the NIOSH limit exceeded the PACU nurses' breathing zone as levels read more than two ppm.

					group 1 and 4.7% in group 0.	
Hiller et al,[15] 2015	To measure sevoflurane WAG concentration in PACU while also accounting for factors that affect inhaled agents' elimination.	Observational pilot study Level II	Conducted in the PACU at Memorial Hermann Hospital in Texas. Air exchangers were verified to meet NIOSH standards for ventilation. Constant variables with normal distribution were registered as standard deviation, while skewed were reported as median and interquartile range. SAS 9.3 was utilized to perform all statistical analyses.	20 adult day surgical patients meeting the research inclusion criteria were selected with an additional requirement of remaining in the PACU for at least an hour. Intraoperatively end-tidal sevoflurane levels and temperature were logged at 10 minutes intervals from induction until extubation. In PACU, emanated WAG from the patient breathing zone was calculated with a portable, calibrated Miran 1B infrared spectrophotometer, with a usable	The median duration of the anesthetic was 100 minutes, and the concentration was 2.1. The maximum sevoflurane WAG concentration exceeded recommended exposure limits in the patient breathing zone for every 5 minutes of measurement.	Exposure levels exceeded recommended limits for the PACU nurses during the measurement times.

				range of 0.03 to 100 ppm. A wand is attached to the analyzer and positioned for measurement at 8 inches directly above the patient mouth during the first phase of recovery.		
Herzog-Niescery et al,[16] 2019	To assess the PACU workers' environmental and biological sevoflurane burden during patient care.	Prospective observational study Level II	A prospective observational study was conducted in a German University Hospital between 2017 and January 2018. Microsoft Excel and IBM SPSS version 20 were utilized for statistical analysis.	Air pollution samples were taken in the PACU and corridor around the PACU area with a photoacoustic gas monitoring device. Pollution was measured at the height of 150cm ten times for nine hours, and the patient's breathing zone was measured 25 times in one hour. Pre-and post-urine sevoflurane and	Air pollution in the center of the PACU unit mean sevoflurane levels was 0.34 ± 0.07 ppm, and a max of 4.43 ± 2.37 ppm daily. In the patient's breathing zones, the daily max was 1.74 ± 1.54, and the mean was 0.44 ± 0.10	PACU workers are biologically and environmentally exposed to sevoflurane during patient care as there were measurable gas peaks and increased significantly from baseline during regular working hours.

				HFIP levels were measured.	ppm. The mean sevoflurane level was 0.47 ± 0.06 ppm in the corridor and was substantially elevated than in the PACU. Urinary sevoflurane and HFIP levels were increased from their pre-shift baseline.	
Heiderich et al,[14] 2018	To assess levels of inhaled anesthetics agents to the number of patients, ventilator settings, and room size in different PACU.	Prospective observational study Level II	The measurement was taken with a compact closed gas loop high-resolution ion mobility spectrometer to trace sevoflurane concentration.	Two PACU in Hannover Medical School in Germany were researched for one week. One hundred forty patients were monitored in PACU 1 and 70 in PACU 2.	In PACU 1, the peak detected level of sevoflurane was 0.96 ± 0.20 ppm, and the median was 0.34 ppm, although it fluctuated	Occupational limits were not exceeded in the samples collected

				Automated samples were taken every 5 minutes in the center of the room. The Shapiro-Wilk test was utilized for the study's statistical analysis.	over time. In PACU 2, the highest detected level of sevoflurane was 0.82 ± 0.07 ppm, with a median of 0.28 ppm.	
McGlothlin et al,[11] 2014	To evaluate the efficacy of a new scavenging and control WAGs in PACU.	Descriptive and comparative study Level III	Patients were brought to the PACU still intubated and extubated in the PACU to set up a standardized start time for WAG measurement. The ISO-Gard mask was put on the patient face once extubated. A certified outside contractor conducted airflow and air exchange assessments	The study included 19 patients: a control group of 9 patients utilizing a nasal cannula or face mask and 10 cases with ISO-Gard utilization. Samples were taken from 6 inches over the patient's nose and mouth with a Miran wand for about 50 minutes for each patient. IR spectrophotometers were used to	Using the standard deviation and means formulas, the average nurses' exposure to nitrous oxide at six inches for the control group compared to the case study group was 69.10 ± 62.77 and 23.99 ± 28.57 ppm, respectively. At	Exposure to nitrous was 2.9 times increased than that of nurses whose patient was utilizing an ISO-Gard mask at six inches. While at three feet, there was a 1.6 times increase. Similarly, at both six inches and three feet, exposure levels were substantially elevated in exposed nurses

			before the commencement of the research and seven months after.	quantify nitrous oxide and sevoflurane levels. It was positioned above the patient's head.	approximately three feet, the average nurse's exposure to nitrous oxide is 11.91 ± 5.61 ppm when the nasal cannula is utilized. In contrast, the average nurse's exposure to nitrous oxide is 7.40 ± 4.61 ppm when the ISO-Gard mask is utilized. Sevoflurane levels at six and three feet were significantly reduced when an ISO-Gard was used compared to when just a nasal cannula	compared to the control group at sevoflurane exposure.

					was used. It was approximately 2.7 times higher.	

DISCUSSION

Most of the literature focuses on mitigating WAG exposure in the OR environment. The critical period for a patient during recovery is the first hour. The perioperative provider needs increased vigilance and direct care; however, the first hour is also attributed to significantly increased WAGs in the breathing zone of a patient who received inhaled anesthetic agents. 5 studies highlighted the concentration of WAGs in the PACU. Although the studies were conducted in different locations, with similar inclusion criteria, sample sizes, and methodology, four conclusions were identical. The findings concluded that the levels of WAGs exceeded the NIOSH recommended limit, especially during the first fifteen minutes to an hour, putting PACU nurses at increased risk for exposure and adverse health effects.[8,11,15,16] However, 1 of the studies did not detect a significant number of WAGs in the PACU; instead, it detected just traces.[14]

Short-and long-term effects were documented in the literature, although debatable. Three studies by different authors highlight various adverse health effects attributed to WAG exposure, including genotoxicity and increased variation in hematologic, immunological, and hepatic parameters.[2,9,13] CBC reflected a substantial reduction in hemoglobin, hematocrit, platelets, and red blood cells, while white blood cells, granulocytes, and lymphocytes were significantly increased.[2] With micronucleus frequency in PBL and BECs substantially increased, it reflects high chromosomal instability and genotoxicity, the main factor in the carcinogenic process.[9] Additionally, all the hepatic biomarkers were elevated in the exposed group.[2] In all 3 studies, the variables measured were substantially higher than the control group consisting of other specialties not exposed to WAGs in the OR and PACU. Thus, it is safe to conclude that PACU nurses are at increased risk for adverse effects than nurses of other specialties. Most studies were

conducted over a short span, the longest being over five months. As a result, data for the long-term effects of WAG exposure are inconclusive.

ORGANIZATION ASSESSMENT

Purpose/Objective

Traditionally, the PACU is not perceived as a workspace with increased risk for WAGs exposure, which is why scavenging systems are not routinely used. This quality improvement project's primary goal and desired outcome are to increase the providers' knowledge based on the current literature, the potential dangers of WAG exposure, and ways perioperative personnel can reduce their exposure levels. The population of focus is perioperative providers. Intervention is an educational module on WAGs exposure and ways to mitigate its adverse effects. The outcome is to increase provider knowledge of WAGs effects and adherence to safety practices.

Goals/Outcomes

The acronym SMART was used to aid in developing the goals, objectives, and outcomes of this project. SMART stands for specific, measurable, achievable, realistic, and timely.

Specific

Perioperative providers at a large hospital will be provided with an educational module detailing the potential for WAG exposure in the PACU and the resulting short- and long-term adverse health effects recommended evidence-based practice for the reduction of WAGs exposure.

Measurable

By utilizing surveying software such as Qualtrics, a pre-survey and post-test survey will be disseminated to the perioperative providers at a large hospital to assess the effectiveness of the educational module.

Achievable

Collaborating with an in-facility preceptor to implement the virtually administered educational module ensures the goal is achievable.

Realistic

Perioperative providers will be educated on WAGs exposure, thus increasing providers' knowledge and adherence to WAG exposure reduction practices.

Timely

The educational module development would be completed within a 4-month time frame and made available to the perioperative providers at a large hospital for three weeks. Additionally, the full implementation of practice recommendations and the evaluation of outcomes would be done over 2-months.

SWOT Analysis

To ensure the success of a project and prepare for potential hindrances, it is vital to perform a SWOT: strengths, weakness, opportunities, and threats analysis. As a result, one can plan and create potential solutions ahead. As the project aims to increase perioperative providers' awareness of the effects of WAGs exposure and engagement in practices that decrease exposure levels, an essential step is the identification of stakeholders. Stakeholders include nurses, physicians, and healthcare organizations.

Strengths

The educational module's ultimate focus is increasing perioperative awareness of the occupational dangers inhaled anesthetic agents carry and, as a result, engaging in preventative practices that decrease the risk of exposure to WAGs. A study by Boiano and Steege showed that providers lacked precautionary practices to differing degrees.[5] Another study by Williams et al.[8]

sampled an ISO-Gard mask in the PACU to reduce exposure to WAGs. It concluded that the mask was effective in reducing the amount of exposure.

Weakness

The assessment of the weaknesses includes issues that can cause a hindrance to the implementation of the educational module. They can include the organizational culture when it comes to implementing change.[17] Additional factors one has to account for include the leadership style of the hospital, the degree of cooperation, the dominant characteristics, and the level of employee involvement in the change process.[18] For example, it will be challenging to be a change agent in an organization that does not promote change and involves its employees in the change process.

Opportunities

Implementing an educational module for perioperative providers on the risk for exposure of WAGs in the PACU, thus increasing awareness and precautionary practices, creates an opportunity to decrease the exposure of WAGs. Hence, the short-term and long-term effects are decreased as a result. Short-term effects linked to WAG exposure include syncope, headache, dizziness, and fatigue during working hours, which can pose patient safety concerns, particularly impaired judgment.[13] Long-term effects include immune system alterations, hepatic alterations, genotoxicity, cancer, and miscarriage.[2,4,13]

Threats

Potential threats to implementing the project include funding, the turnover rate, the overwhelming schedule of the stakeholder, or a lack of interest.[17] Especially because the implementation of the project lacks incentives, it is vital that the stakeholders are self-motivated and interested in mitigating the exposure of WAGs in the PACU.

DEFINITION OF TERMS

Waste anesthetic gases (WAGs):

Are small amounts of volatile anesthetic gases that leak into the environment.[2]

Breathing zone:

It is an area encompassing the face of approximately 6 to 9 inches.[8]

THEORETICAL FRAMEWORK

Vital to implementing the educational module on WAGs exposure is using a middle-range theory to aid in the process. Specifically, Lewin's change theory involves unfreezing, moving, and refreezing.[19] The first step is unfreezing, which entails recognizing that the current practices are no longer the best way to utilize them. This step also factors in the driving and restraining forces of change. The next step is moving, which entails implementing a comprehensive educational program that includes current literature on decreasing WAGs exposure. Finally, the refreezing stage ensures that implementation stays and becomes the new status quo.[19] To facilitate the final step, once the project is successfully implemented, evaluation of adherence via surveys will be performed, and yearly retraining will reinforce and ensure permanent incorporation at the large hospital.

METHODOLOGY OF QUALITY IMPROVEMENT PROJECT

Setting and Participants

Following the Institution Review Board at Florida International University's approval, this quality improvement project was conducted at a large, private, not-for-profit teaching hospital in Florida. Surgical procedures such as general surgery, gynecologic, urologic, thoracic, reconstructive, plastic, orthopedic, neurosurgery, radiation, and diagnostic imaging require various anesthetic techniques. An estimated 13,000 surgical procedures are performed yearly,

most performed in an outpatient setting. The quality improvement project participants comprised only Certified Registered Nurse Anesthetists (CRNAs) with a total of 10.

Protection of Human Subjects

Depending on the Institutional Review Board's grade risk scale on the proposed project, participants' consent will be obtained via Qualtrics, a HIPAA-compliant software. CRNAs working at the large hospital were invited to be involved in the project via their work email. Participation was voluntary, and subjects could withdraw their consent at any time. Potential benefits to participants include improved knowledge and awareness of WAGs exposure in the PACU and, as a result, engaging in preventative practices that decrease exposure. Aside from mild emotional stress or mild physical discomfort from sitting on a chair for an extended period during the completion of the educational module, participants are not expected to experience any significant risk, harm, or discomfort during this project. Data on participant knowledge, perceptions, and practices regarding exposure to waste anesthetic gases were collected anonymously. Data was password-protected, and only investigators had access to the information.

Intervention and Data Collection

The project intervention started with the invitation of CRNAs at the large hospital through Qualtrics via their work email to participate. The education module was limited to 10 minutes to keep the participants' attention. Before providing the educational module, a pre-test survey via Qualtrics was given to assess the nurse's knowledge of WAG exposure, adverse effects, and practices that reduce its exposure. After implementing the educational module, a post-test survey via Qualtrics was given. The educational module contained WAGs exposure,

occupational risk, adverse effects, and evidence-based practices to decrease exposure. Demographical data included age, sex, race, and years of practice.

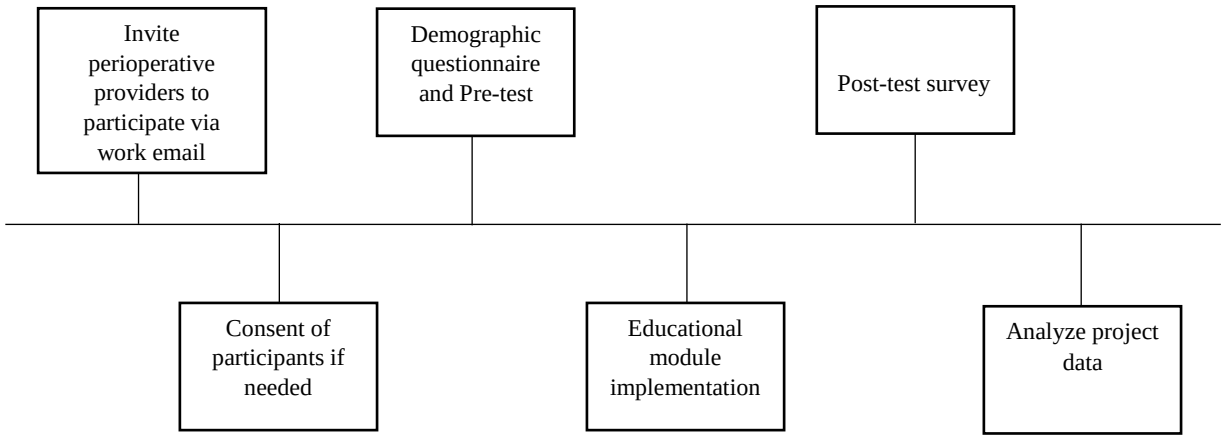
Data Management and Analysis Plan

The data collected were stored electronically, and access was limited to the primary investigator. Based on the nature of the project, no direct participant identifier was needed, negating the need to collect any identifiable information. A random identifier number was assigned to the participants; thus, the data collected was anonymous. Statistical data analysis compared the survey results before and after implementing the educational module.

TIMELINE

Project Tasks

1. Development of the education module
2. Development of demographic and pre-test survey
3. Choose a HIPPA-compliant software platform to utilize for the project
4. Choose an electronic database to store and compile project data
5. Write up an informed consent
6. Request IRB approval
7. Create and disseminate project invite
8. Administer pre-test survey
9. Implement educational module
10. Administer posttest survey
11. Review and compile participants' progress
12. Analyze project data



RESULTS

Participant Demographics

After the launch of Qualtrics, 10 participants completed the survey. Female participants accounted for 60% (*n* = 6), 30% (*n* = 3) were males, and 10% (*n* = 1) preferred not to specify. The survey participants encompassed individuals from various racial/ethical backgrounds, such as 40% Hispanics, 30% African Americans, 20% Caucasians, and 10% Asians. All the participants were CRNAs; however, 60% (*n* = 6) were Doctoral degree level, and 40% (*n* = 4) were master's degree level. The participants had varying levels of experience; 1 to 2 years (*n* = 1, 10%), 2 to 5 years (*n* = 3, 30%), 5 to 10 years (*n* = 2, 20%), and over 10 years (*n* = 4, 40%). The participants' demographics are illustrated in Table 1.

Table 1. Demographics

Demographics	**N (%)**
Total Participants	10 (100%)
Gender	
Male	3 (30 %)
Female	6 (60 %)
Prefer not to say	1 (10 %)
Ethnicity	
African American	3 (30 %)
Caucasian	2 (20 %)
Hispanic	4 (40 %)
Asian	1 (10 %)
Medical Profession	
Doctorate	6 (60 %)
Masters	4 (40 %)
Experience	
1 to 2 years	1 (10 %)
2 to 5 years	3 (30 %)
5 to 10 years	2 (20 %)
Over ten years	4 (40 %)

Pre-Test: Assessment of Baseline Knowledge

The pre-test questions were administered to assess the baseline knowledge of the participants. The test was administered prior to the implementation of the educational module. In contrast, the post-test was administered after implementing the educational module. The pre-test result is shown in Table 2. The pre-and-post-test consisted of identical questions listed below:

1. What organization is responsible for setting exposure limits to waste anesthetic gases?
    a. National Institute for Occupational Safety and Health
    b. Food and Drug Administration

   c. Occupational Safety and Health Administration
   d. Department of Transportation

2. Which providers are NOT at-risk for waste anesthetic gas exposure?
   a. OR nurses
   b. PACU nurses
   c. Nurse anesthetists
   d. ICU nurses
   e. Surgeons
3. Short-term effects of waste anesthetic gases include?
   a. Genotoxicity
   b. Cancer
   c. Difficulty with judgment
   d. Kidney disease
4. Long-term effects of waste anesthetic gases include?
   a. Infertility
   b. Headache
   c. Fatigue
   d. Nausea
5. True or False. Chronic exposure to waste anesthetic gases has been linked to short- and long-term effects?
   a. True
   b. False
6. True or False. Waste anesthetic gas exposure can be eliminated?

a. True

b. False

7. How likely are you to ensure the proper functioning of the scavenging system?

    a. Most likely

    b. Somewhat likely

    c. Somewhat unlikely

    d. Most unlikely

8. How likely are you to utilize an ISO-Gard mask?

    a. Most likely

    b. Somewhat likely

    c. Somewhat unlikely

    d. Most unlikely

The results of pre-test questions 7 and 8 are illustrated in Figures 1 and 2. The responses based on question 7 on the pre-test were as follows, 3 (30%) answered "extremely unlikely," 2 (20%) answered "neither likely nor unlikely," 1 (10%) answered "somewhat likely," and 4 (40%) answered "extremely likely." While question 8, feedback was as follows, 3 (30%) answered "extremely unlikely," 3 (30%) answered "somewhat unlikely," 2 (20%) answered "neither likely nor unlikely," and 1 (10%) answered "somewhat likely," and 1 (10%) answered "extremely likely."

Table 2. Pretest Results

Question Number (#)	Number of participants that answered correctly	Percentage of the correct answer
#1	2/10	20%
#2	6/10	60%
#3	5/10	50%
#4	6/10	60%
#5	9/10	90%
#6	6/10	60%

Figure 1. Pre-test question 7

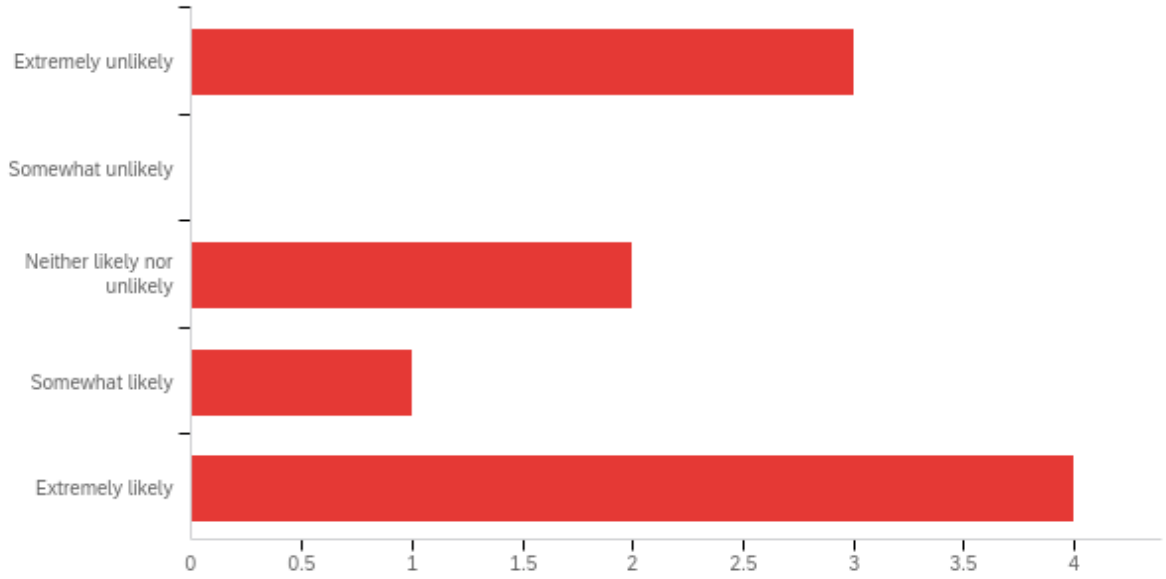
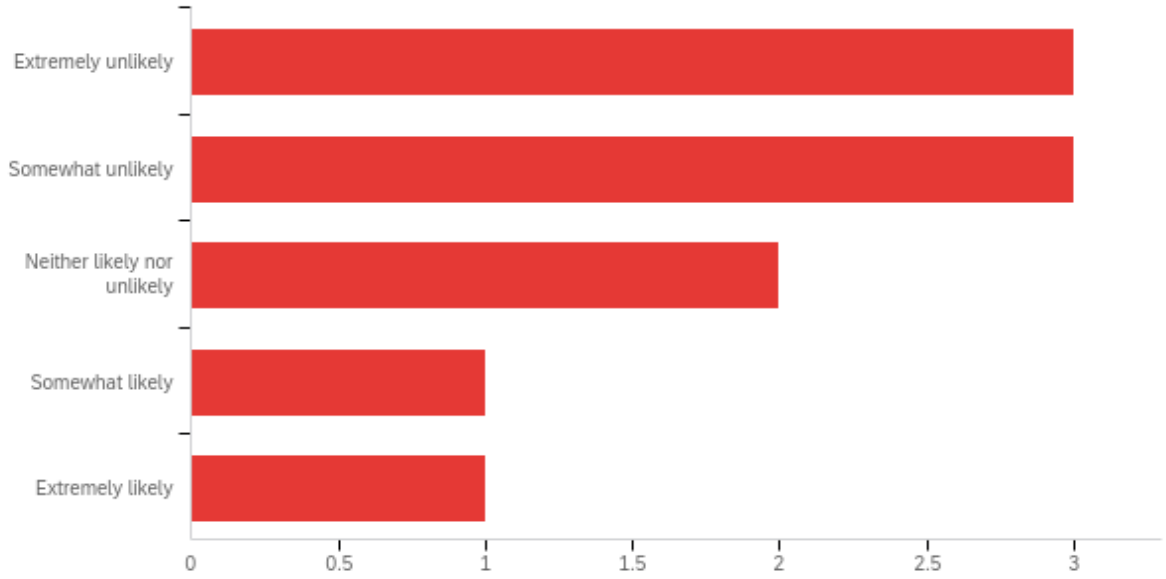


Figure 2. Pre-test question 8



Post-Test: Assessment of Learning

The post-test was administered after the implementation of the educational module. It was administered to assess knowledge gained after the module's presentation and the probability of the participants utilizing the suggested practices to reduce WAGs exposure level. Participants demonstrated improved scores in the post-test survey compared to the pre-test scores. When asked how likely they are to ensure the proper functioning of the scavenging system in the post-test, 6 (60%) CRNAs responded "extremely likely," and 1 (10%) responded "extremely unlikely." Furthermore, when asked how likely they are to utilize an ISO-Gard mask, 4 (40%) CRNAs responded "extremely likely," 3 (30%) CRNAs responded "somewhat likely," and 3 (30%) CRNAs responded "extremely unlikely." Results for post-test questions 1 through 6 are shown in Table 3, and question 7 through 8 is shown in Figures 3 and 4. While Table 4 illustrates the improvement in scores after implementing the educational module.

Figure 3. Post-test Question 7

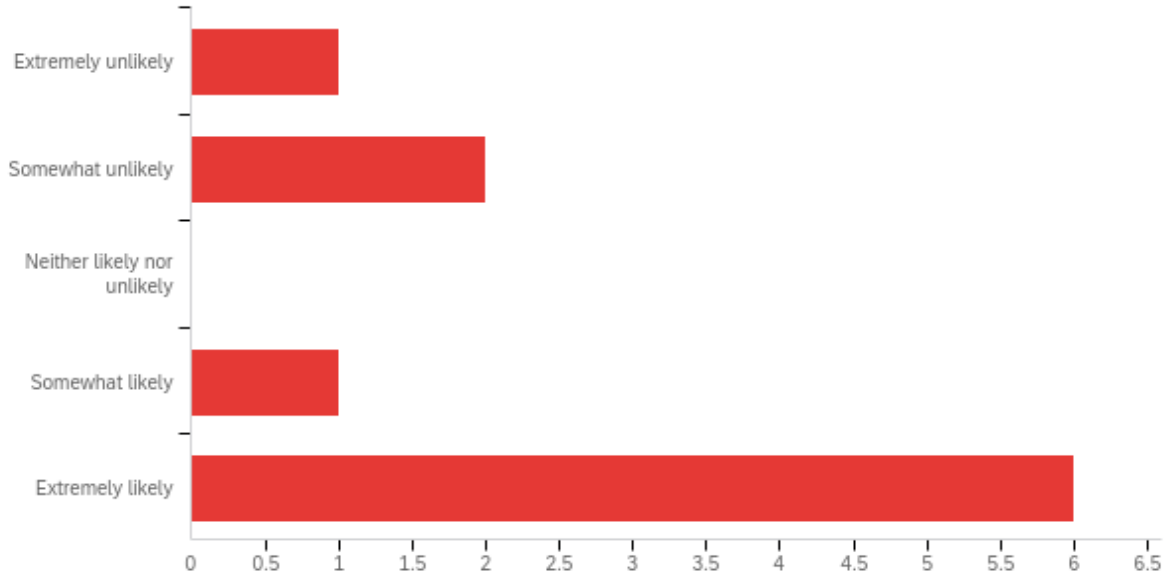


Figure 4. Post-test Question 8

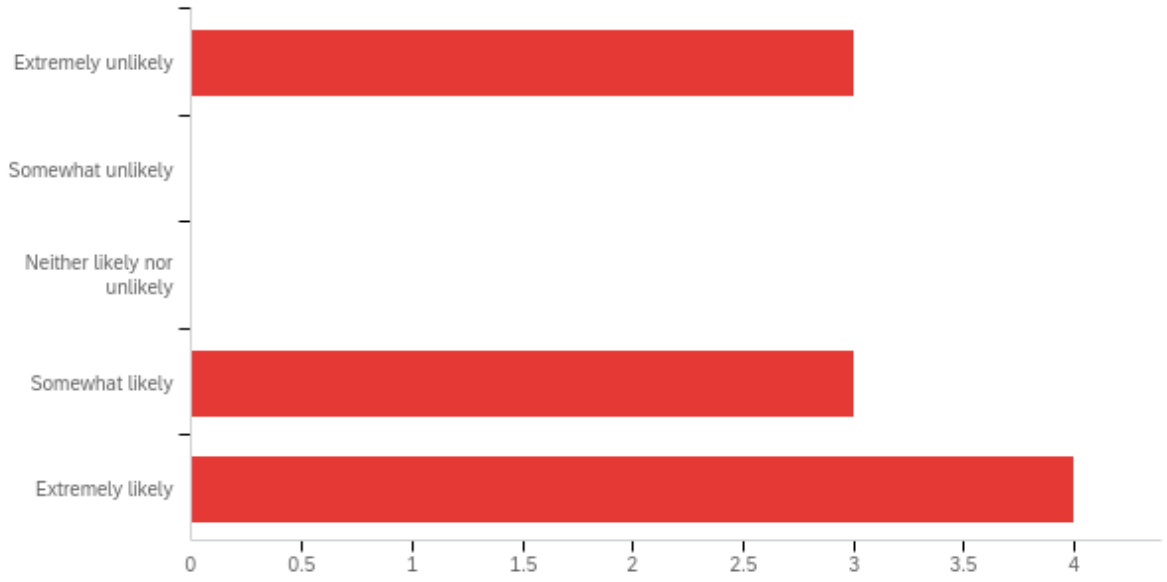


Table 3. Post-test Results

Question Number (#)	Number of participants that answered correctly	Percentage of the correct answer
#1	8/10	80%
#2	7/10	70%
#3	7/10	70%
#4	9/10	90%
#5	10/10	100%
#6	7/10	70%

Table 4. Pre-test vs. Post-test scores

Question Number (#)	Pre-test score percentage	Post-test score percentage	Change
#1	20%	80%	+60%
#2	60%	70%	+ 10%
#3	50%	70%	+20%
#4	60%	90%	+30%
#5	90%	100%	+10%
#6	60%	70%	+10%

DISCUSSION

The virtually administered educational module showed increased knowledge regarding WAG exposure, its adverse effects, and practices that reduce its exposure when comparing the pre-test to the post-test survey results. After implementing the module, 80% (n = 8) answered question 1 correctly, showing a 60% increase in knowledge for the organization responsible for setting exposure limits to WAGs. Results showed a 20 to 30% increase in the participant's ability to distinguish between the short- and long-term effects of WAGs exposure. 70% (n = 7) of

participants identified at-risk providers to WAG exposure as opposed to 60% (*n* = 6) during the pre-test survey. 100% (*n* = 10) of the participants knew that chronic WAGs had been linked to short- and long-term effects. Additionally, 70% of participants correctly acknowledged that WAGs exposure could not be eliminated. However, when asked about the likelihood of ensuring the proper functioning of the scavenging system. 60% (*n* = 6) of the participants responded that they were "extremely likely," and 10% (*n* = 1) responded "extremely unlikely." when it comes to the utilization of an ISO-Gard mask, 40% (*n* = 4) responded, "extremely likely," 30% (*n* = 3) responded "somewhat likely," and 30% (*n* = 3) responded "extremely unlikely."

Limitations

The most significant limitation of the quality improvement project was the sample size. The educational module was disseminated to 34 CRNAs via their work email using Qualtrics; 1 email bounced back and thus could not be delivered. However, after a reminder email was sent prior to the closure of the Qualtrics link, only 10 CRNAs completed the survey. Another limitation to consider is the virtual format of the quality improvement project. It creates a unique type of limitation as supposed to deliver it in person. One must consider the technological literacy of the invited participants. Additionally, dissemination via email tends to be easily overlooked, the invitees may need to be more active users of their email accounts, and there is limited control over ensuring the participants initiate or complete the survey.

IMPLICATIONS OF ADVANCED PRACTICE NURSING

With the first hour being the critical period for a patient during recovery, studies have shown that levels of WAGs exceeded the NIOSH recommended limit, especially during the first fifteen minutes to an hour. Perioperative providers in the PACU are at increased risk for exposure and adverse health effects.[8,11,15,16] Most of the literature review analyzed focused on

mitigating WAG exposure in the OR environment. Hence, implementation of WAGs reduction practices in the PACU is limited. Implementing the educational module highlighted the need to increase perioperative provider awareness of WAGs exposure in the PACU. As a result of newly gained knowledge, participants are willing to engage in evidence-based prevention practices. With the proper tool and education, perioperative providers ensure their safety while providing quality care. Further research on WAG exposure and reduction practices in the PACU is still needed.

CONCLUSION

After implementing the educational module with a total participant of 10, results showed increased knowledge regarding WAG exposure, its adverse effects, and practices that reduce its exposure when comparing the pre-test to the post-test survey results. There was a 60% increase in knowledge for the organization responsible for setting exposure limits to WAGs. Also, a 20% to 30% increase in the participant's ability to distinguish between the short- and long-term effects of WAGs exposure. 70% (n = 7) of participants identified at-risk providers to WAG exposure as opposed to 60% (n = 6) during the pre-test survey. All 10 participants knew that chronic WAGs had been linked to short- and long-term effects.

Additionally, more than half of the participants knew that WAGs exposure could not be eliminated. 60% (n = 6) strongly desired to ensure the proper functioning of the scavenging system. Regarding utilizing an ISO-Gard mask, 40% (n = 4) were extremely likely, and 30% (n = 3) were somewhat likely. Considering the limitations of the project and little research focused on mitigating WAGs exposure in the PACU, further research is needed.

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Appendix A

CONSENT TO PARTICIPATE IN A QUALITY IMPROVEMENT PROJECT
"Increasing providers' awareness of waste anesthetic gases exposure in the post-anesthetic care unit: An educational module"

SUMMARY INFORMATION
Things you should know about this study:

- **Purpose:** Educational module to increase providers' awareness of waste anesthetic gases exposure in the post-anesthetic care unit
- **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 expected in any educational intervention, which may include mild emotional stress or mild physical discomfort from sitting on a chair for an extended period.
- **Benefits:** The main benefit to you from this research is increasing the participant's knowledge on the risk for exposure to waste anesthetic gases in the post-anesthetic care unit and, as a result, engaging in preventative practices that decrease exposure.
- **Alternatives:** There are no known alternatives available other than not participating in this quality improvement project.
- **Participation:** Taking part in this quality improvement 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. This project aims to increase providers' knowledge of the potential dangers of waste anesthetic gases exposure in the post-anesthetic care unit, along with ways in which perioperative personnel can reduce their exposure levels.

NUMBER OF PARTICIPANTS
If you decide to participate, you will be 1 of approximately 10 participants.

DURATION OF THE PROJECT
Your participation will require about 20 minutes of your time.

PROCEDURES
If you agree to be in the project, we will ask you to do the following things:
If you agree to be in the study, 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 15 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 research is minimal. There will be minimal risks involved with this project, as expected in any educational intervention, which may include mild emotional stress or mild physical discomfort from sitting on a chair for an extended period.

BENEFITS
The following benefits may be associated with your participation in this project: An increased participants' knowledge on the risk for exposure to waste anesthetic gases in the post-anesthetic care unit, and as a result, engaging in preventative practices that decrease exposure.
The program's overall objective is to increase the providers' knowledge based on the current literature.

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

CONFIDENTIALITY
The records of this project will be kept private and will be protected to the fullest extent provided by law. Records will be stored securely, and only the project team will have access to the records. 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.

PARTICIPATION: Taking part in this quality improvement project is voluntary.

COMPENSATION & COSTS
There is no cost or payment to you for receiving the health education and/or 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 when they feel it is in their best interest.

RESEARCHER CONTACT INFORMATION

If you have any questions about the purpose, procedures, or any other issues relating to this research project, you may contact Blessing Lukoh at 786-314-0383/bluko001@fiu.edu and Yasmine Campbell at 305-778-0722/ ycampbel@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 study. I have had a chance to ask any questions I have about this study, and they have been answered for me. I am providing my informed consent by clicking on the "consent to participate" button below.

Appendix B

Pretest and Posttest Questionnaire:

Waste Anesthetic Gases in PACU

INTRODUCTION

The primary aim of this QI project is to increase providers awareness of waste anesthetic gases exposure in the post-anesthetic care unit.

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 on waste anesthetic gases exposure in PACU

PERSONAL INFORMATION

1. **Gender:** Male Female Other_____
2. **Ages 25 and above: _____**
3. **Ethnicity:** Hispanic Caucasian African American Asian Other_____
4. **Position/Title:** CRNA Anesthesiologist Resident
5. **Level of Education:** Bachelors Masters Doctorate Other _____
6. How many years have you been a perioperative provider?

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

QUESTIONNAIRE

9. **What organization is responsible for setting exposure limit to waste anesthetic gases:**
    a. National Institute for Occupational Safety and Health
    b. Food and Drug Administration
    c. Occupational Safety and Health Administration
    d. Department of Transportation
10. **Which of the following providers is NOT at-risk for waste anesthetic gases exposure:**
    a. OR nurses
    b. PACU nurses
    c. Nurse anesthetists
    d. ICU nurses
    e. Surgeons
11. **Short-term effects of waste anesthetic gases include:**
    a. Genotoxicity
    b. Cancer
    c. Difficulty with judgment
    d. Kidney disease
12. **Long-term effects of waste anesthetic gases include:**
    a. Infertility
    b. Headache
    c. Fatigue

d. Nausea

13. Chronic exposure to waste anesthetic gases has been linked to short- and long-term effects?

a. True

b. False

14. Waste anesthetic gases exposure can be totally eliminated?

a. True

b. False

15. How likely are you to ensure the proper functioning of the scavenging system?

a. Most likely

b. Somewhat likely

c. Somewhat unlikely

d. Most unlikely

16. How likely are you to utilize an ISO-Gard mask?

a. Most likely

b. Somewhat likely

c. Somewhat unlikely

d. Most unlikely

Appendix C

Miami Beach Anesthesiology Associates, Inc.

Mount Sinai Medical Center • Division of Anesthesia

S. Howard Wittels MD Chairman
Hector Davila MSS, MD Executive Director
Guillermo Garcia MD Vice Chairman
Rick Hasty MD
Sebastian Baquero MD
Christopher Bauer MD
Vicente Behrens MD
Jayanand D'Mello MD Research Coordinator
Laura Foster MD
Pablo Fumero MD
Pedro Garcia MD
Howard Goldman MD Obstetrics Chief
Jason Hoyos DO Residency Program Co-Assistant Director
Flor Marin MD
Gerald Rosen MD Residency Program Director
Jason Wigley MD Residency Program Co-Assistant Director
Alexander Volsky MD
Jennifer Wright MD
J.P. Mato DNP, CRNA CRNA Director & SRNA Coordinator
Paula Schultz DNP, CRNA OB-Chief CRNA

February 1, 2022

Dr. Yasmine Campbell, DNP, CRNA, APRN
Assistant Professor
Department of Nurse Anesthesiology
Florida International University

Dr. Campbell,

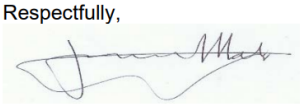
Thank you for inviting Mount Sinai Medical Center to participate in Doctor of Nursing Practice (DNP) project conducted by Blessing Lukoh entitled "Increasing Providers Awareness of Waste Anesthetic Gases Exposure in The Post-Anesthetic Care Unit: An Educational Module" in the Nicole Wertheim College of Nursing and Health Sciences, Department of Nurse Anesthesiology at Florida International University. I have given the student permission to conduct the project using our providers.

Evidence-based practice's primary aim is to yield the best outcomes for patients by selecting interventions supported by the evidence. This proposed quality improvement project seeks to investigate and synthesize the latest evidence.

We understand that participation in the study is voluntary and carries no overt risk. All Division of Anesthesia providers are free to participate or withdraw from the study at any time. The educational intervention will be conveyed by a 15-minute virtual PowerPoint presentation, with a pretest and posttest questionnaire delivered by a URL link electronically via Qualtrics, an online survey product. Responses to pretest and posttest surveys are not linked to any participant. The collected information is reported as an aggregate, and there is no monetary compensation for participation. All collected material will be kept confidential, stored in a password encrypted digital cloud, and only be accessible to the investigators of this study: Blessing Lukoh and Dr. Campbell.

Once the Institutional Review Board's approval is achieved, this scholarly project's execution will occur over two weeks. Blessing Lukoh will behave professionally, follow standards of care, and not impede hospital performance. We support the participation of our Division of Anesthesia providers in this project and look forward to working with you.

Respectfully,



Jampierre (J.P.) Mato, DNP, CRNA, APRN
Executive CRNA Director
SRNA Coordinator/Supervisor
Electronic Mail: Jampierre@bellsouth.net
Mobile Phone: 954-668-6080

Appendix D

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Office of Research Integrity
Research Compliance, MARC 414

MEMORANDUM

To: Dr. Yasmine Campbell

CC: File

From: Chris Grayson, MBA, CIM, CIP, Director, Research Integrity

Date: March 25, 2022

Protocol Title: Increasing providers awareness of waste anesthetic gases exposure in the post-anesthetic care unit: An educational module.

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-22-0107 **IRB Exemption Date:** 03/25/22
TOPAZ Reference #: 111526

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.

Appendix E

Dear Miami Beach Associates Providers,

You are invited to participate in a quality improvement project titled "Increasing providers awareness of waste anesthetic gases exposure in the post-anesthetic care unit: An educational module" via the Qualtrics platform. This project is being conducted by Blessing Lukoh, SRNA at Florida International University (FIU). This study aims to increase the providers' knowledge based on the current literature, the potential dangers of WAGs exposure, along with ways in which perioperative personnel can reduce their exposure levels. The results may be reported in aggregated and presented in advocacy communications, journal articles, poster presentations, and lectures. This study is a doctoral project.

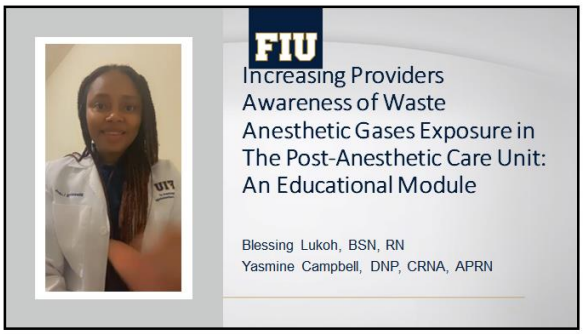
Participation in this survey is entirely voluntary. You may choose not to participate or to opt or skip the survey at any time. Regardless of your decision, there will be no effect on your relationship with the researchers or any other consequences. Best practices will be utilized to protect the confidentiality of survey data. The survey should take approximately 10-15 minutes to complete.

The Institutional Review Board has approved this project of FIU. The main risk or discomfort from this research is minimal. There will be minimal risks involved with this project, as expected in any educational intervention, which may include mild emotional stress or mild physical discomfort from sitting on a chair for an extended period. All responses to this survey will remain anonymous and cannot be linked to the participant. In addition, you may choose to omit the demographic questions included in the survey if you find them potentially identifiable. No personal identifying information about you will be collected during the study, and your survey will be identified only with a random number sampling. Once you submit your completed survey, there will be no way to withdraw your responses from the study because the survey data contains no identifying information and will be unable to be traced back to your submission. While you may not experience any direct benefits from participation, you will be contributing to a body of knowledge supporting the profession.

If you have any questions about the purpose, procedures, or any other issues relating to this research project, you may contact Blessing Lukoh at 786-314-0383/bluko001@fiu.edu and Yasmine Campbell at 305-778-0722/ ycampbel@fiu.edu. If you would like to talk with someone about your rights to be a subject in this project, you may contact the FIU Office of Research Integrity by phone at 305-348-2494 or email at ori@fiu.edu.

Sincerely,
Blessing Lukoh SRNA.
Yasmine Campbell, DNP, CRNA, APRN.

Appendix F



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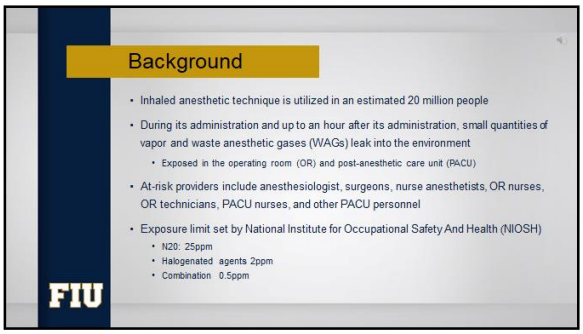

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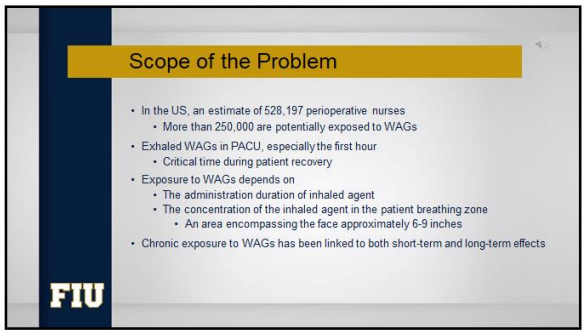

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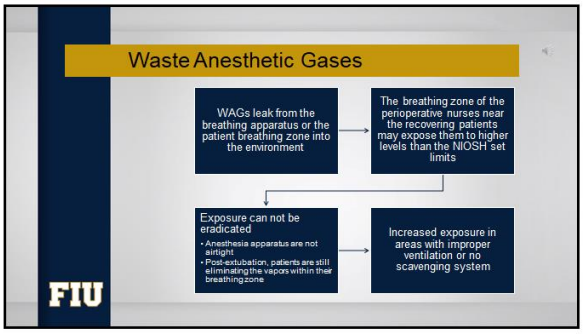

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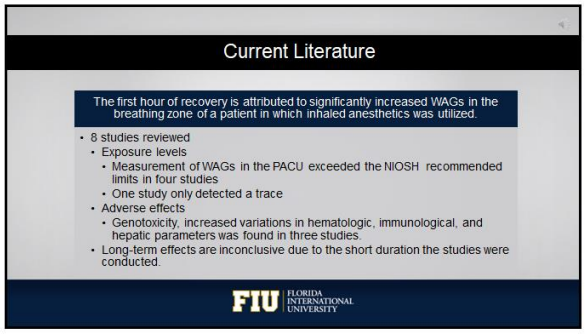

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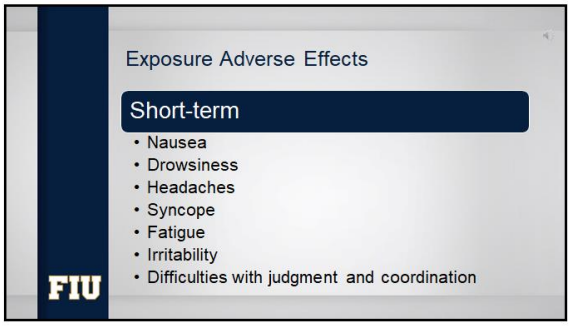
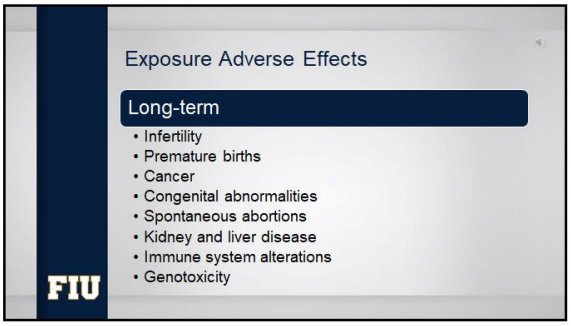
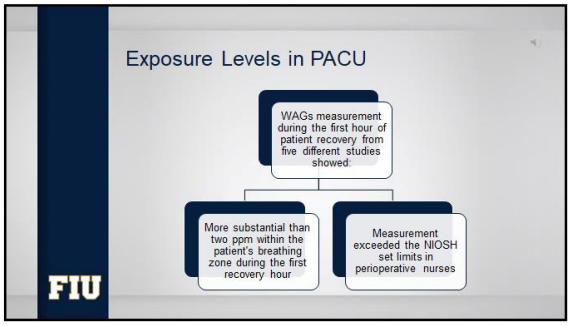

Exposure Adverse Effects
Short-term
• Nausea
• Drowsiness
• Headaches
• Syncope
• Fatigue
• Irritability
• Difficulties with judgment and coordination
FIU

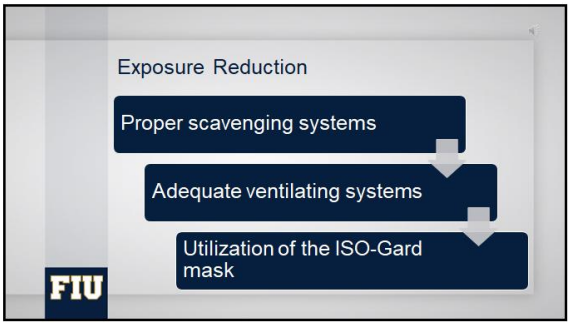
7


Exposure Adverse Effects
Long-term
• Infertility
• Premature births
• Cancer
• Congenital abnormalities
• Spontaneous abortions
• Kidney and liver disease
• Immune system alterations
• Genotoxicity
FIU

8


Exposure Levels in PACU
WAGs measurement during the first hour of patient recovery from five different studies showed:
More substantial than two ppm within the patient's breathing zone during the first recovery hour
Measurement exceeded the NIOSH set limits in perioperative nurses
FIU

9


Exposure Reduction
Proper scavenging systems
Adequate ventilating systems
Utilization of the ISO-Gard mask
FIU

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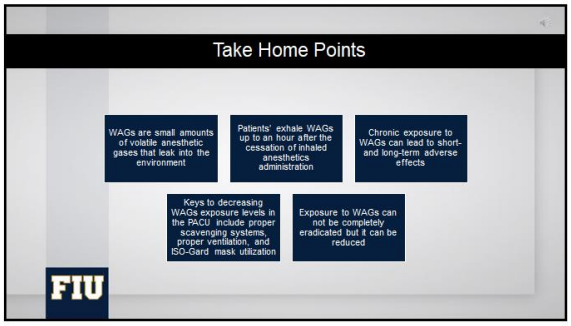
Take Home Points
WAGs are small amounts of volatile anesthetic gases that leak into the environment
Patients' exhale WAGs up to an hour after the cessation of inhaled anesthetics administration
Chronic exposure to WAGs can lead to short- and long-term adverse effects
Keys to decreasing WAGs exposure levels in the PACU include proper scavenging systems, proper ventilation, and ISO-Gard mask utilization
Exposure to WAGs can not be completely eradicated but it can be reduced
FIU

11


References
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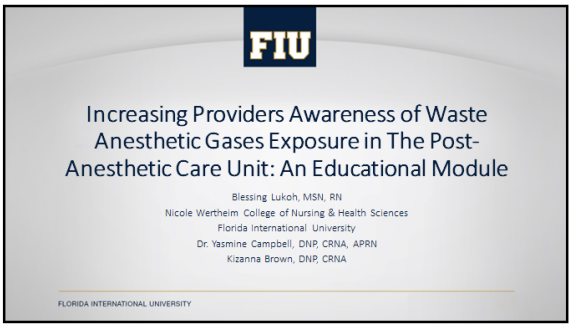
Appendix G



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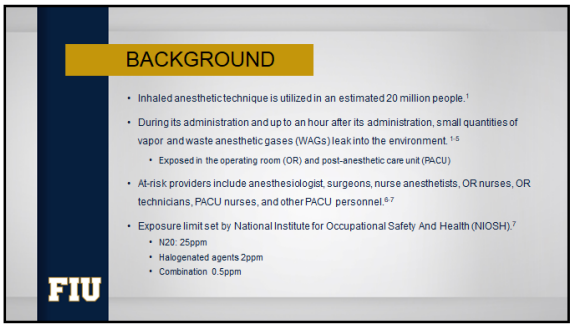

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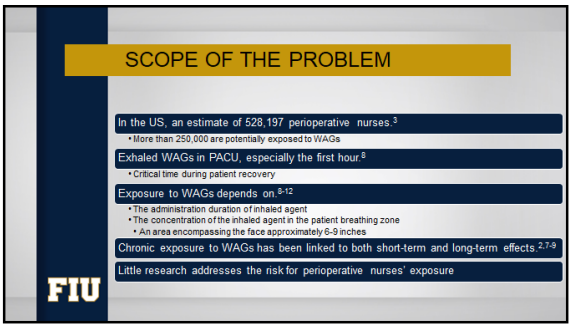

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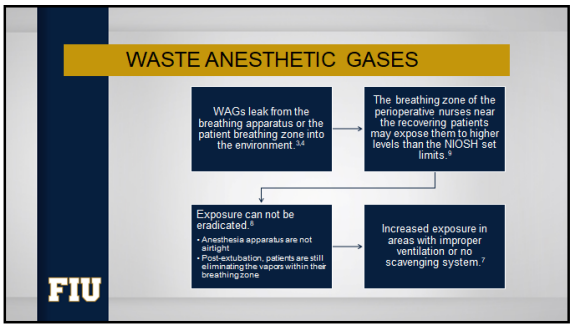

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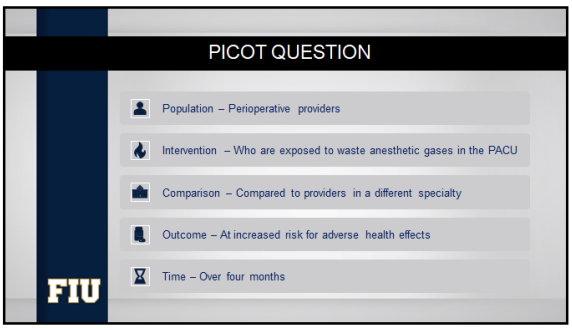

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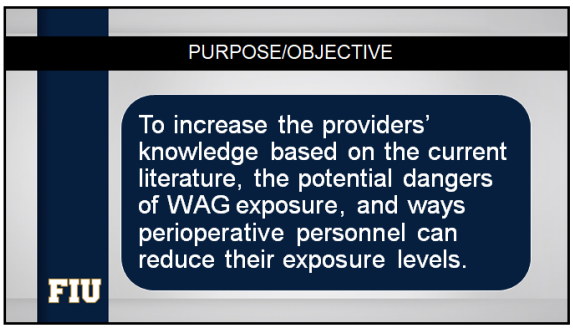

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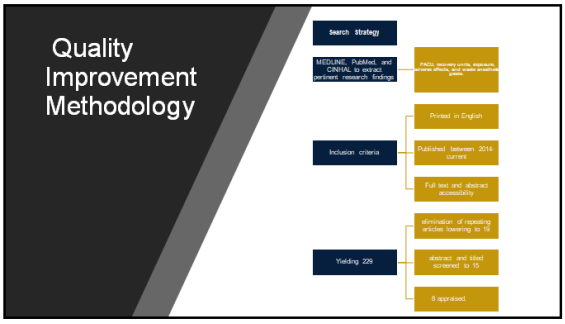
Quality Improvement Methodology
Search strategy
MEDLINE, PubMed, and CINHAL to extract pertinent research findings
PADs, recovery units, exposure, adverse effects, and waste anesthetic gases.
Inclusion criteria
Printed in English
Published between 2014-current
Full text and abstract accessibility
Yielding 229
elimination of repeating articles lowering to 19
abstract and titled screened to 15
8 appraised.

7


Quality Improvement Methodology
Setting
A large, private, not-for-profit hospital in Miami Beach, FL
Participants
A total number of 10 CRNA's
Methods
Pre-test survey
An educational module
Post-test survey
Analysis
Qualtrics results exported to excel software to analyze data and evaluate responses from pre-test and post-test survey
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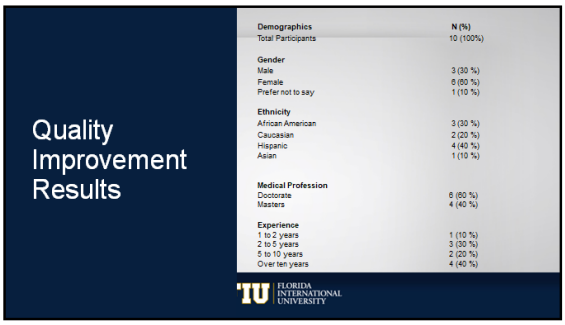
Quality Improvement Results
Demographics
N (%)
Total Participants
10 (100%)
Gender
Male
3 (30 %)
Female
6 (60 %)
Prefer not to say
1 (10 %)
Ethnicity
African American
3 (30 %)
Caucasian
2 (20 %)
Hispanic
4 (40 %)
Asian
1 (10 %)
Medical Profession
Doctorate
6 (60 %)
Masters
4 (40 %)
Experience
1 to 2 years
1 (10 %)
2 to 5 years
3 (30 %)
5 to 10 years
2 (20 %)
Over ten years
4 (40 %)
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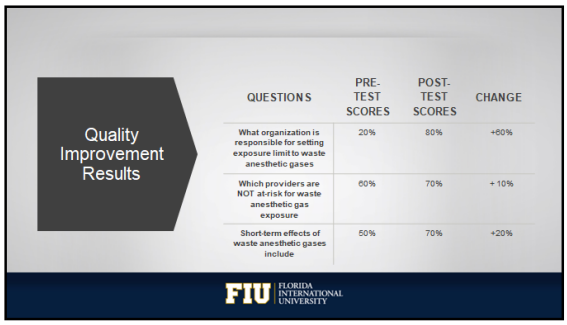
Quality Improvement Results
QUESTIONS
PRE-TEST SCORES
POST-TEST SCORES
CHANGE
What organization is responsible for setting exposure limit to waste anesthetic gases
20%
80%
+60%
Which providers are NOT at-risk for waste anesthetic gas exposure
60%
70%
+ 10%
Short-term effects of waste anesthetic gases include
50%
70%
+20%
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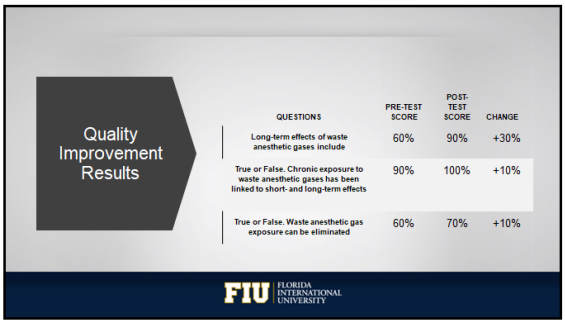
Quality Improvement Results
QUESTIONS
PRE-TEST SCORE
POST-TEST SCORE
CHANGE
Long-term effects of waste anesthetic gases include
60%
90%
+30%
True or False. Chronic exposure to waste anesthetic gases has been linked to short- and long-term effects
90%
100%
+10%
True or False. Waste anesthetic gas exposure can be eliminated
60%
70%
+10%
FIU
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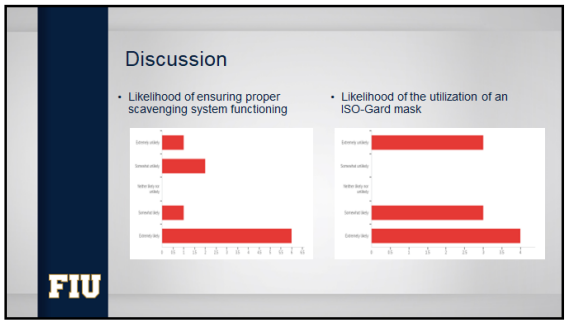
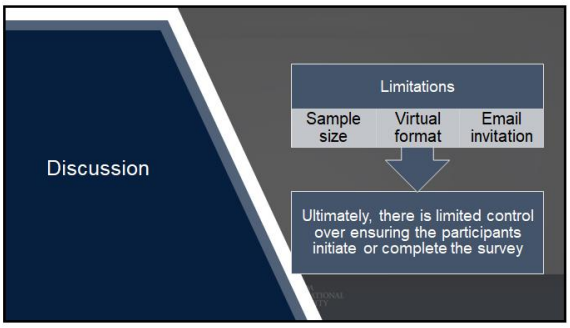

Discussion
Likelihood of ensuring proper scavenging system functioning
Likelihood of the utilization of an ISO-Gard mask
FIU

12



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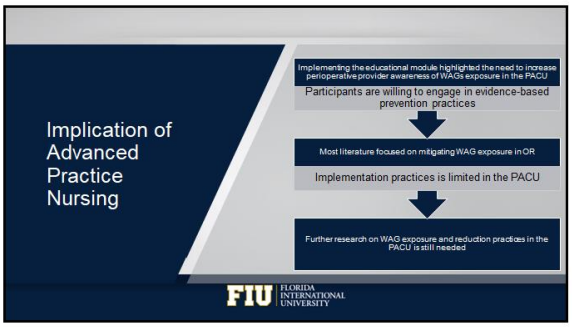

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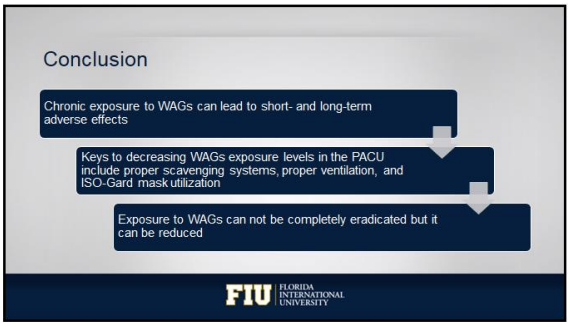

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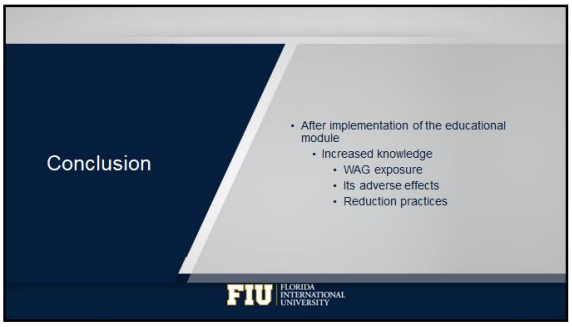

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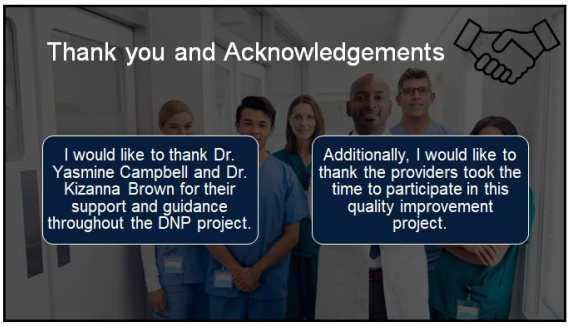

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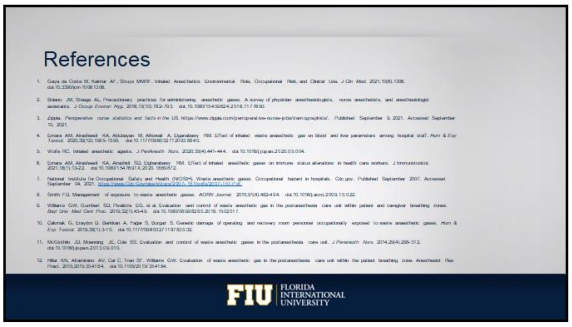

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