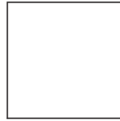

ORIGINAL ARTICLES

Phase I Collaborative Pilot Study: Waste Anesthetic Gas Levels in the PACU

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The National Institute of Occupational Safety and Health (NIOSH) recommends that exposure to waste anesthetic gas (WAG) be minimized to the greatest extent possible. Current recommendations include 2 parts per million (ppm) for 1 hour sample to halogenated agents level or 25 ppm based on nitrous oxide level or combination of 0.5 ppm for halogenated agents and 25 ppm nitrous oxide. The Occupational Safety Health Administration requires that work practices and engineering controls be implemented so that occupational exposure to WAG is controlled. This pilot study was conducted to (1) evaluate the level of WAG in the PACU, (2) analyze the relationship between nurse exposure and self-reported symptoms, and (3) test methods used to describe occupational exposure of PACU staff to WAG. Air sampling to measure levels of WAG in the patient and PACU nurse environment was performed with MIRAN SapphRE (Foxboro Company, Foxboro, MA), a nondispersive infrared spectrophotometer. A personal sampling method was used to measure the level of nurse exposure to WAG on 2 separate days. Self-report of 9 health symptoms using a 10-cm visual analogue scale was obtained before and after the shift from 6 (PACU) nurses. Three nurses from the Medical Intensive Care Unit (MICU) served as a control. Descriptive statistics summarized exhaled gas level and staff exposure. The highest concentrations of nitrous oxide were 283 to 295 ppm in the patient's breathing zone, whereas halogenated agents were below the limit of detection. Staff exposure to nitrous oxide ranged from 2.9 to 8.2 ppm, averaged over the work shift. T test of the pre- and postshift symptoms showed no significant difference in both PACU and MICU nurses. This pilot study identified the potential for staff exposure to WAG in the PACU setting. The methods to detect this exposure were also evaluated. It is recommended that further study be conducted to evaluate PACU staff exposure to WAG. Modifications in some of the measurement methods tested here are also suggested, including the use of procedures to measure the efficacy of air exchange and other engineering controls related to staff exposure.

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THE PURPOSES OF this pilot study were to evaluate the level of waste anesthetic gas (WAG) in the PACU, to analyze the relationship between nurse exposure and self-reported symptoms, and to test methods used to describe occupational exposure of staff to WAG. Many studies have been conducted to determine occupational exposure to anesthetic gas in dental clinics and ORs.[1-5] However, the PACU and other ICUs that receive patients directly from the OR have not been commonly studied or routinely monitored for WAG levels. Concerns among the PACU staff about exposure to WAG provided the impetus for this study (personal communication).

The OR is designed to prevent patient exposure to infectious agents. Highly purified air is directed down across the operating field at the rate of at least 15 air exchanges per hour.[6] This exchange equates to the air volume of the room and forces any WAG to be directed away from the breathing zone of the OR staff. Additionally, the amount of air flowing through the OR ensures that any WAG in the room is quickly diluted.

The PACU at the Johns Hopkins Hospital is designed for 6 air exchanges per hour with supply and exhaust vents spaced throughout the room. This study was designed to address the following questions.

Research Questions

1. What is the level of WAG within the patient's environment (breathing zone) and staff working area?
2. Is there a relationship between level of WAG in the patient's environment and level of WAG in the staff work area?
3. Is there a relationship between the level of WAG in the staff working area and level of staff exposure to WAG?
4. Is there a relationship between staff exposure to WAG and incidence and severity of symptoms experienced by the staff?
5. How effective are the current study methods in evaluating WAG in the patient's environment and the staff work area?

Operational Definitions

1. Waste anesthetic gas: nitrous oxide and halogenated agents (halothane, isoflurane, and sevoflurane) detectable by nondispersive infrared spectrophotometer and measured in parts per million (ppm) in the air.
2. Patient's environment or breathing zone: a hemisphere of 9 inches in diameter comprising the patient's head.
3. Staff working area: the foot of the patient's bed (most common location where PACU nurses at the Johns Hopkins Hospital sit to observe the patient) and the nurses' station.
4. Staff exposure to waste anesthetic gas: Levels of anesthetic gas detected on personal sampling monitors and measured in ppm.
5. Symptom severity: score on the Symptom Survey.
6. Effectiveness of study methods: the extent to which the proposed study methods measure WAG in the patient environment and the staff work area in the PACU setting.

Literature Review

The National Institute for Occupational Safety and Health (NIOSH)[7] is unable to identify a safe level of exposure for WAG. However, NIOSH recommends that the risk be minimized by reducing exposures to the greatest extent possible.[7-9] The NIOSH recommended exposure level (REL) is 2 ppm during use of halogenated agents and 25 ppm for nitrous oxide.[8] The American Conference of Governmental Industrial Hygiene (ACGIH) recommends a threshold limit volume (TLV) of 50 ppm for nitrous oxide and halothane, using an 8-hour time-weighted average.[10] The Occupational Safety Health Administration (OSHA) requires that work prac-

Table 1. Anesthetic Agents and Related Symptoms

Agent	Symptoms
Nitrous oxide	Dyspnea, drowsiness, headache, asphyxiation, reproductive effects
Halothane	Irritated eyes, skin, and respiratory system; confusion, dizziness, nausea, analgesia, anesthesia, cardiac dysrhythmia; liver and kidney damage; decreased audio-visual performance; and reproductive effects in animals
Isoflurane	Eye irritation and redness, skin dryness and irritation; irritation to mouth and throat, dizziness, headache, drowsiness, and death
Sevoflurane	Cardiac dysrhythmia, suspect renal and hepatic damage, malignant hyperthermia

Data from National Institute of Occupational Safety and Health.[9]

tices and engineering controls be implemented so WAG is controlled, providing employees a workplace free of recognized hazards.[11,12]

NIOSH describes the characteristics of anesthetic agents and the adverse symptoms associated with exposure to these agents (Table 1).[8] These adverse health effects of exposure to WAG have been the subject of several studies and much debate for over 50 years. Tannenbaum and Goldberg[2] reviewed 77 studies between the 1960s and the 1980s. They noted that many of these early studies contained methodologic flaws such as inadequate comparison groups and sample sizes. Therefore, they concluded that there was inadequate evidence to state that occupational exposure to anesthetic agents was harmful.[2]

Later studies with greater methodologic rigor supported the notion that nitrous oxide is associated with harmful effects in health care workers. For example, an epidemiologic study conducted by Cohen, the American Dental Association, and NIOSH reported that nitrous oxide exposure among dental workers was associated with a 1.7-fold increase in kidney disease, a 1.8-fold increase in liver disease, and a 2.8-fold increase in neurologic symptoms of numbness, tingling, and muscle weakness.[1]

Rowland et al[3] surveyed 459 dental assistants and, after controlling for covariates, found that women who were exposed to high levels of nitrous oxide were significantly less fertile than women who were unexposed or exposed to low levels of nitrous oxide. Guirguis et al[13] evaluated 8,032 persons exposed or not exposed to anesthetic gas and found a significant increase in spontaneous abortions among personnel exposed to more than 2 hours of anesthetic gas per week.

Tran et al[14] studied the presence of nitrous oxide in 12 ORs and nitrous oxide exposure levels among 281 hospital staff using personal monitoring dosimetry. Ninety-nine of the staff were exposed to nitrous oxide and 182 were not exposed. The investigators found that 4 of the 12 ORs studied exceeded the threshold of 50 ppm. This level was twice that recommended by NIOSH. Nitrous oxide exposure was the highest in anesthetists, followed by scrub nurses.[14]

Using a simulated PACU environment, Austin and Austin[15] showed that the concentration of nitrous oxide decreases with distance from the patient. The patient's respiration increases the level of nitrous oxide at the location of the nurse, who is in the patient's environment. The respiration of the nurse pulls the flow field toward the nurse, increasing the nurse's exposure to the gas.[15] Badgwell[16] found that a system designed to recover anesthetic gas waste at its source is effective in reducing WAG in the atmosphere in the PACU setting. Beyond the Austin and Badgwell studies, however, there has been little information in the literature concerning the level of anesthetic gas waste in the patient's environment and the staff working area in the PACU setting.

Based on the findings of Austin and Austin[15] that the concentration of nitrous oxide decreases with distance from the patient, the highest level of staff exposure to WAG potentially could be during the patient's admission. It is during this time that the nurse is closest to the patient, monitoring the patient's airway, assess-

Fig 1. Bed location in the PACU. Bed numbers 1 to 9 are primary areas for short stay PACU patients. Bed numbers 18 to 20 are used as secondary areas whenever the primary areas are occupied. Beds 12 and 13 are used for contact isolation patients (not frequently used). The middle section of the unit (bed number 10 to 11 and 14 to 17) is designated for AICU patients who stay overnight. For the purpose of the study, the nurses who were measured for WAG levels were assigned to bed numbers 1 to 9.

ing vital signs, and encouraging the patient to breathe deep and cough. Other risk factors unique to the PACU that could increase the possibility of exposure to airborne pathogens are as follows: (1) a PACU is commonly designed as one large room without any walls between patients, which may result in cross contamination of WAG; (2) the narrow distance between patients; (3) the high occupancy and rapid turnover of patients; and (4) staff responsibilities that dictate how much time is spent in close proximity to the patient.

Methods

This pilot study measured levels of WAG in the patient environment and staff working area. The relationship of these anesthetic gas levels to staff exposure level as well as the incidence and severity of health symptoms were also explored. The study was conducted for 2 days (Friday and Monday) at The Johns Hopkins Hospital in the main PACU. The Medical Intensive Care Unite (MICU) and a small sample of nurses who practice there were selected as the control group.

MICU nurses were selected as the control group because they have no exposure to patients in the postoperative period and should therefore have no exposure to anesthetic gas waste. Although MICU nurses do not care for patients who have received anesthesia, they do practice in a critical care environment with a similar stress level to that of the PACU. Because some of the health symptoms such as headache and fatigue may also be associated with the stress of the working environment, the control group was included to control for this effect. Friday and Monday were selected because those days included the greatest number of patients scheduled for surgery.

PACU Description

The PACU is one large room about 1,950 square feet that accommodates 20 beds. There are 12 beds on one side of the room designated for short-term patients with a length of stay (LOS) of 2 to 5 hours. Six beds are designated for the anesthesia ICU (AICU) patients who stay overnight in the same room but are located in the middle part of the room. The last 2 beds are

Fig 2. Air supply vents in the PACU.

designated for patients requiring contact isolation and are located on the right side of the room (Fig 1).

Air supply vents are located at the sides of a drop ceiling and project inside the perimeter of the room. They are designed to provide 6 air exchanges per hour. Two supply ducts also are located in the ceiling in the center of the room. The return air ducts are located between one and 4 feet above the finished floor in 2 of the columns near the center of the room. The PACU is under positive pressure relative to the rest of the building. The exhaust from the PACU is discharged through the roof of the building into the atmosphere (Figs 2 and 3).

Sample

A convenience sample of 9 nurses volunteered as subjects. This included 6 PACU and 3 MICU nurses. Nurses who had chronic headaches were excluded from the study. Twenty-eight

Fig 3. PACU air supply and return ducts.

patients who were admitted to the PACU for the 2 days between 9:00 AM and 4:30 PM were assessed for the presence of WAG in their breathing zone. This included patients that were newly admitted to the PACU beds each day and AICU patients who were admitted to the PACU a minimum of 10 to 12 hours before the time the investigators measured the WAG on the 2 study days.

A patient's breathing zone WAG level is an indication of the amount of agents the patient is exhaling. Sixty percent of these patients had received general anesthesia. Both patients who had received general and regional anesthesia were included because of the possibility that patients who receive regional anesthesia may exhale WAG inhaled from the PACU environment.

Instruments/Data Collection Tools

Instruments were selected to measure the extent of gas waste in the patients' and nurses' environment and to assess the extent to which nurses experienced symptoms associated with exposure to anesthetic gas waste.

1. A nondispersive infrared spectrophotometer (205 A Series Miran SapphIRe; Foxboro Company, Foxboro, MA) is a portable ambient air analyzer consisting of infrared filters that samples ambient air to detect the presence of predefined gases and the amount of gas concentration.
2. Personal Sampling Monitors (ChemDisk; Assay Technology, Pleasanton, CA) are designed to measure individual exposure to gaseous agents. Each PACU nurse wore 2 badges: one for halogenated anesthetic gases and one for nitrous oxide.
3. A Patient Intraoperative Information Form is part of the current Anesthesia Data Record for the hospital. Information from this form was obtained concerning the type of anesthesia delivered and the agents used. This form provided additional information about the source of the gas waste measured in the patient's breathing zone. Also, the method of oxygen delivery was obtained from this form in case this influenced the level of gas measured in the patient's breathing zone.
4. The Symptom Survey is a 9-item self-report survey developed by the investigators from the literature on health effects of exposure to anesthetic gases.[13,14] The scale uses a 10-cm visual analogue scale to measure severity of 9 symptoms: headache; anxiety; lethargy/fatigue; irritation of eyes, nose, and throat; reduction in concentration; decrease in audiovisual ability; numbness or tingling in extremities; muscle weakness; and nausea. The scale for each item ranges from 0 (no experience of the symptom) to 10 (the most severe experience of that symptom). The total score for the symptom survey has a potential range from 0 to 90. A master's-prepared PACU nurse and an assistant professor of medicine/environmental health sciences reviewed the survey for content validity and for clarity before use in this study (Fig 4).

Procedure

After institutional review board approval, written informed consent to participate in this study was obtained from all subjects. The subjects completed the Symptom Survey Form before the start and at the end of their shift.

Two personal sampling monitors were attached to each PACU nurse's collar. One personal sampling monitor measured the halogenated anesthetic gas waste levels and one measured the nitrous oxide waste level. (In the MICU the personal sampling monitor was not used. However, the MICU room air was analyzed using the nondispersive infrared spectrophotometer to ensure that no anesthetic agents were present.)

Fig 4. Symptom survey form.

PACU WAG levels were measured before the newly admitted patients arrived in the PACU each morning. At each patient's admission, the WAG levels were measured within the patient's breathing zone and at the foot of the bed. These same measures were taken for AICU patients who had been in the PACU for 10 to 12 hours before the study began with the first newly admitted PACU patient on each study day. The measurements were repeated on newly admitted patients every hour until the level returned to the background state of the room or until the patient was transferred or discharged. During the study, patients either had a face mask or nasal cannula. Nurses attempted to wean patients from the face mask or nasal cannula within an hour of admission.

The nurses completed the self-reported symptom surveys and returned the personal sampling monitors at the end of their 8-hour shift. The duration of exposure monitoring ranged between 4 and 6 hours per nurse. This represented the actual hours of patient care excluding nurse's break time and/or professional time. The manufacturer required that the tempera-

Fig 5. Nitrous oxide over time line graph (patient breathing zone and foot of the bed).

ture and relative humidity of the personal sampling monitor be evaluated before each use. After use, the personal sampling monitors were sealed in the pouches provided by the manufacturer and refrigerated pending shipment to Assay Technology (Pleasanton, CA) for analysis.

Nurses received reports from the anesthesia care providers (ACPs) during the patient's admission to PACU. Therefore, the PACU nurses knew the anesthetic gas used in the OR. However, they were blinded to gas concentration measurements. Two investigators gathering the gas measurements were blinded to nurses' symptoms and the anesthetic gas used in the OR. Another investigator gathering the nurses' symptoms was informed regarding the gas used in the OR but was blinded to gas concentration measurements. Neither the nurses nor the investigators had information about nurse exposure until the results of the laboratory analysis were received. During the study, the peak patient census was at 60% to 65% of capacity. This indicated that the unit was moderately busy.

Results

Figure 5 shows the difference between the nitrous oxide levels between the patients' breathing zone and the nurses' environment at admission and 1, 2, and 3 hours after admission. The overall mean nitrous oxide level at the patients' breathing zone was 11.19 ppm, and 3.41 ppm in the nurses' environment.

Table 2 shows the personal sampling monitor results obtained from 6 PACU nurses. Nurses A, B, C, D, and E were assigned to PACU beds 1 to 9 during their assigned shifts. Nurse F was the charge nurse and floated within the PACU to assist with patient admissions. The patient census on Friday was 50% and on Monday was 65% of PACU capacity. This is important to note because a census closer to capacity could be

Table 2. Personal Sampling Monitor Results (2-Day Survey)

	Nurse A (Beds 1-3)	Nurse B (Beds 4-6)	Nurse C (Beds 7-9)	Nurse D (Beds 10-11)	Nurse E (Beds 14-16)	Nurse F (Floater/Charge)
Friday, day 1						
Sample time	4.77 h	6.03 h	NR	5.15 h	4.17 h	4.17 h
Anesthetic agent						
Nitrous oxide	*	2.9 ppm	NR	3.9 ppm	2.8 ppm	5.6 ppm
Halothane	<0.031 ppm	<0.025 ppm	NR	*	<0.036 ppm	<0.033 ppm
Isoflurane	<0.084 ppm	<0.066 ppm	NR	*	<0.096 ppm	<0.089 ppm
Sevoflurane	<0.013 ppm	<0.099 ppm	NR	*	<0.14 ppm	<0.13 ppm
Monday, day 2						
Sample time	4.68 h	4.9 h	4.77 h	NR	NR	5.79 h
Anesthetic agent						
Nitrous oxide	5.5 ppm	7.6 ppm	8.2 ppm	NR	NR	2.9 ppm

Abbreviation: NR, not recorded.
*Below detection level.

Table 3. Summary of Recommendations/Nurses' Exposure Levels

Agent	NIOSH Recommendations	ACGIH Recommendations	Nurses' Exposure Levels (Personal Sampling Monitor)
Nitrous oxide	25 ppm*	50 ppm‡	2.8 to 8.2 ppm/6 hr
Halothane	2 ppm†	50 ppm‡	Nonquantifiable
Isoflurane	2 ppm†	None	Nonquantifiable
Sevoflurane	2 ppm†	None	Nonquantifiable

NOTE. Nitrous oxide, 2 ppm at the nurses station and 2 ppm at the egresses. Halogenated agents, nonquantifiable in both nurses station and egresses.
*Eight-hour time-weighted average.
†One-hour time-weighted average.
‡Eight-hour time-weighted average over a 40-hour work week.

associated with a higher level of WAG in the PACU environment.

Table 3 compares the staff exposure levels to WAG that were measured using the personal sampling monitor and the NIOSH and ACGIH recommended maximum exposure levels on nitrous oxide and halogenated agents. ACGIH is an internationally recognized organization that reviews toxicologic data on chemical exposure and formulates exposure levels to which workers may be exposed repeatedly without adverse health effects (ACGIH, Threshold limit).

Figure 6 shows the mean total symptom scores of PACU and MICU nurses before the start of their work shifts. Nurses in the PACU scored 5.31, whereas nurses in the MICU scored 5.33 of a potential 90 points, with higher scores indicating greater symptom severity. There was no significant difference in the mean total symptom scores between the 2 groups ($t = -.007$, $df = 15$; $P = .99$).

Fig 6. Preshift symptom score for PACU and MICU nurses.

Figure 7 shows the mean symptom score between PACU and MICU nurses after working an 8-hour shift. The mean PACU nurse score was 4.84, whereas the mean MICU nurse score was 10.33 of a potential 90 points, with higher scores indicating a greater severity of symptoms. Because of the small sample size, one nurse who experienced a severe headache at the end of the shift and reported a total symptom score of 10 skewed the mean symptom score of the MICU. When a *t* test was performed, there was no significant difference in the symptom scores between these 2 groups ($t = -.84$, $df = 2.2$, $P = .48$).

Discussion

Figure 5 clearly shows a higher concentration of nitrous oxide at the patient's breathing zone compared with the foot of the bed. Because the investigators had measured the level of WAG at the patient's admission to the PACU and for each hour thereafter until transfer, or until the WAG level reached background room level, they were surprised that the peak of waste nitrous oxide gas level within the patient's breathing zone was one hour after admission. They had expected the peak WAG level to be at admission when the patient had most recently received the anesthetic agents. Two factors may

Fig 7. Postshift symptom score for PACU and MICU nurses.

have contributed to this increase. First, after one hour in the PACU, the patients were awake and breathing more regularly than they were at admission. Second, the patients who were admitted from the OR with oxygen via facemask were advanced to nasal cannula or weaned to room air by the first hour in the PACU. The oxygen via facemask could have controlled the release of WAG at admission, causing an increase in the release of WAG upon discontinuation of the mask. The precise contribution that the facemask and the patients' level of alertness made to the increased WAG level was not clear.

Table 2 shows the exposure of staff. Friday and Monday were selected because they were projected to be the high census days. On day one (Friday), overall exposure of the staff was below 4 ppm nitrous oxide with the exception of the charge nurse (Nurse F). This may reflect the duties of the charge nurse requiring the nurse to assist with newly admitted patients (the time of the greatest rate of exhalation of WAG). The patient load on day 2 was 30% higher than day one as is indicated by the higher overall exposure of the staff. The charge nurse on this day was assisting with a patient who had not received gas anesthetics. However, the charge nurse still had a detectable exposure to nitrous oxide, and her isoflurane exposure was similar to that of other nurses.

Cross contamination of infectious agents is another concern in the PACU because of the open space and close proximity of patients. During the pilot study, the investigators incidentally measured an example of cross contamination. On Monday, the first patient in the PACU had epidural anesthesia and had a nondetectable gas concentration level within the patient's breathing zone. The second patient had a general anesthesia and was 10 feet away from the first patient. This second patient had 295 ppm concentration of nitrous oxide level within the patient's breathing zone during the admission phase. At this time, the first patient had a repeat measurement and showed an increase from zero to 150 ppm of nitrous concentration level. This illustrated the contamination of the air and potential exposure not only to staff, but also to other patients.

Table 3 compares the summary of staff exposure levels to WAG and NIOSH and ACGIH recommended exposure levels on nitrous oxide and halogenated agents (halothane, isoflurane, and sevoflurane). Currently, OSHA has not set a permissible exposure limit for WAG. However, under the General Duty Clause of OSHA, an employer must provide employees a work area free of recognized hazards. In this study, the nurses' exposure to nitrous oxide using the personal sampling monitor method was below the exposure level of nitrous oxide as recommended by NIOSH and ACGIH. Also, the nurses' exposure to halogenated agents was nonquantifiable. Because the nurse routinely spends a shorter period of time near the patient's breathing zone (high concentration) than at the foot of the bed (low concentration), the

results of the exposure monitoring were expected. It is possible that the personal sampling monitor method may detect high-level gas exposures as could be found in an OR when scavenging equipment malfunctions. However, this method may not be sensitive enough to measure lower levels of staff exposures that occur in the PACU environment.

During the study, the unit occupancy was fairly low (50% on Friday and 65% on Monday). Also, only 60% of the patients in the PACU on these days had received inhalation agents. A higher occupancy and higher number of patients who had inhalation agents could increase the exposure of the staff to WAG. Although the staff exposure is lower than the NIOSH recommendation, NIOSH stated that they are unable to identify a safe level of exposure for WAG. Therefore, NIOSH recommends that the risk be minimized by reducing exposures to the greatest extent possible (NIOSH, US Department of Health).

MICU nurses were selected as the control group because the intensity of the care required by MICU patients was similar to that of PACU patients. Also, the patients being treated for medical problems were unlikely to have been given anesthetic agents. As expected, the WAG level in MICU was nondetectable. The preshift self-reported health symptoms (Fig 6) showed a mean symptom score of 5.31 among the 5 PACU nurses and 5.33 among the 3 MICU nurses. In the postshift assessment (Fig 7), the PACU nurses had a mean symptom score of 5.0, and the MICU nurses had a mean score of 10. The increase in the MICU nurses' mean score was caused by one nurse who had a severe headache at the end of the shift. However, a *t* test found no significant difference in the mean symptom score of the PACU and MICU subjects. Because the sample size for each nurse group was so small, one high score skewed the mean total symptom score for the MICU. A larger sample size in subsequent studies should decrease the impact of a single outlier such as this.

This pilot study evaluated other methods of data collection for the purpose of improving the methods for future study. First, the data obtained from the intraoperative information data sheet were too lengthy and demanded unnecessary data collection. Second, WAG levels were measured for newly admitted PACU patients and AICU patients who were admitted to the PACU a minimum of 10 to 12 hours before the time the investigators measured the WAG levels in the PACU new patients. Some of the AICU patients remained overnight. These patients had no WAG level at the breathing zone the next morning, indicating that patients who spend the night in the PACU should be excluded in future studies. The nurses caring for these overnight patients had a lower exposure compared with nurses who received patients immediately after surgery. Future studies should limit the measurement of WAG to patients who are admitted immediately from the OR.

Patients who were on ventilators had a nonquantifiable WAG level at the breathing zone because of the closed system. Future studies should measure WAG in the exhaust system of the patient's ventilator, which is at the back of the machine.

There were some problems with the personal sampling devices that the nurses wore. The sampling media in some of the badges were lost during the nurses' activities. This problem can be prevented easily in future studies by sealing the monitor edges with tape.

The major limitation in conducting personal sampling for exposure is the requirement that the airborne concentration in the area be within the sampling range of the analytical techniques. The OSHA analytical methods are validated within certain concentrations. Normally, the validation range is 0.5, 1.0, and 2.0 times the permissible exposure limit (PEL) with a maximum allowable error of less than 25% at these levels. Because WAG does not have a PEL, target concentrations for validation were selected as

follows: nitrous oxide—12.5 ppm, 25 ppm, 50 ppm, and 100 ppm; and isoflurane—1 ppm (low) and 75 ppm (high). No specific limits for sevothane and desflurane were listed. Airborne concentrations outside these levels could result in larger total errors in the sampling and analytical techniques.

During the prepilot phase, the air sampling time was designed to occur at admission and every 15 minutes. However, this was not feasible because of the simultaneous admission of PACU patients. Therefore, as the study progressed, the time intervals were changed to admission and every hour after until the level returned to the background level or the patient was discharged or transferred. It is possible that a study that includes a more frequent assessment of WAG might more precisely pinpoint the peak WAG level after admission.

Recommendations for future study include that monitoring be performed when the PACU is at full capacity and at average operating conditions to further evaluate the exposure of the PACU staff. Future design of new PACUs should take into consideration the potential exposure of nurses and be designed to capture any WAG as close to the patient as possible. Thus, staff exposure to WAG would be reduced.

Summary

PACU staff concerns about exposure to WAG were the impetus for initiating this pilot study. The study measured WAG levels within the patient's environment and staff work area, measured staff exposure level to WAG, identified incidence and severity of symptoms experienced by the staff, and evaluated how effective the current study methods are in evaluating WAG in the patient's environment and the staff work area.

This pilot study showed a higher level of WAG at the patient's breathing zone compared with the RN's work environment. The PACU staff exposure level to WAG was below the recommended guidelines of NIOSH and ACGIH exposure level. However, NIOSH further recommends that the risk be minimized by reducing exposures to the greatest extent possible.[7-9] Results of pre- and postsymptoms of PACU staff showed no significant difference between PACU and the control group in MICU. The sample size was small, and findings cannot be generalized. Study methods such as the type and amount of data collected, frequency of measuring WAG, and personal monitoring device were evaluated. The results showed that the intraoperative information was too long. The frequency of measuring WAG, specifically the 15 minutes after the patient's admission, was difficult to accomplish because of the number of patients to be measured at the same time.

This pilot study also served as baseline information for the second phase of the study as planned by the investigators. The next phase of the study will explore the use of other methods in measuring WAG in PACU and will compare these measures to the personal monitoring device and the health symptoms reported by PACU staff. It is recommended that further study be undertaken to evaluate PACU staff exposure level to WAG. Modification in some of the measurement methods tested here is suggested, including the use of procedures to measure the efficacy of air exchange and other engineering controls related to staff exposure.

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