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**“HAZARDOUS POST ANESTHESIA CARE UNIT (PACU): REALITY OR MYTH?
A CASE STUDY”**

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ABSTRACT

Research has linked various health problems with chronic exposure to *anesthetic waste gases*. Few studies have explored *anesthetic waste gases* in the *Post Anesthesia Care Unit (PACU)*. Newer halogenated anesthetic agents such as *Sevoflurane* and *Desflurane* have expedient recoveries and theoretically, limit exposure time to *waste anesthetic gases* in *PACU*. Exposure of *recovery room* nurses to *Sevoflurane* was measured in this descriptive study. Sequential air samples from *PACU* nurse's breathing space were taken while they administered routine post operative care. The sample included two *PACU* nurses working day shifts who were assigned to patients only anesthetized with *Sevoflurane*. Other variables of interest were recorded which included; patients' age sex, weight, body mass index (BMI), respiratory rate, MAC hours of *Sevoflurane*, and time from discontinuation of *Sevoflurane* until patients entered monitoring areas in *PACU*. All measurements were within the National Institute for Occupational Safety and Health (NIOSH) standards for *trace anesthetic gases*. Fluctuations in *Sevoflurane* levels occurred and higher levels corresponded with the *PACU* nurse caring for two patients anesthetized with *Sevoflurane* concurrently, in addition, those same patients had higher MAC hours of *Sevoflurane*. In this study of a *PACU* in a medium size hospital, *Sevoflurane* levels did not exceed NIOSH standards for waste anesthetic gases.

Key Words: *waste anesthetic gases, Post Anesthesia Care Unit (PACU), Sevoflurane, recovery room, trace anesthetic gases*

HAZARDOUS POST ANESTHESIA CARE UNIT (PACU): REALITY OR MYTH?

A CASE STUDY

by

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PREFACE

This study was conducted to provide information regarding the hazardous environment of the Post Anesthesia Care Unit. Nurses and technicians working in the Post Anesthesia Care Unit require information regarding the safety conditions of their working environment as mandated by the National Institute for Occupational Safety and Health.

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CHAPTER ONE INTRODUCTION

Background

The top five hazards to anesthesia providers are infectious waste, radiation, laser treatments, chemicals, and anesthetic waste gases (Kole, 1990). Research has linked various health problems with chronic exposure to anesthetic waste gases - a reality which is hard to ignore. However, anesthetic waste gases remain a controversial environmental occupational hazard.

Implementation of scavenger equipment in operating rooms (ORs), has reduced dangerous exposure to anesthetic waste gases. Whitcher, Cohen, and Trudell (1971) found that appropriate scavenger equipment significantly reduces atmospheric pollution in operating rooms, however residual gases can be detected and measured from the exhaled breath of operating room nurses and nurse anesthetists up to 16 hours after exposure. Scavenger units are not utilized in post anesthesia care units (PACU), even though Halothane and nitrous oxide levels are higher in the recovery room than in the operating room. In addition, residual concentrations of Halothane in exhaled breath and in the venous blood of recovery room nurses have also been demonstrated (Pfaffli, Nikki, & Ahlman, 1972 b).

In 1997, Diana McGregor, M.B., chairman of the Task Force on Trace Anesthetic Gases, discussed the issue of anesthetic waste gases. The adverse effects of anesthetic waste gases were first cited in the Soviet Union in 1967. Waste gases were believed to cause harmful effects in OR personnel. These effects included problems with pregnancies and deterioration of nervous systems. This prompted several studies in the 1970s which

confirmed the original speculation of trace anesthetic gases being associated with miscarriages and birth defects. Concerns led to a conference of several government agencies to explore the findings. In 1977, the National Institute for Occupational Safety and Health (NIOSH) promulgated standards for anesthetic delivery systems. All anesthetic gas machines and nonrebreathing systems require effective scavenging devices (NIOSH, 1977).

Studies after 1977 could not replicate deleterious effects (pregnancy problems and deterioration of the nervous system) of trace anesthetic gases, and experts disagreed with previous studies, citing flaws in design, methods of data collection, and poor reliability of outcome data (McGregor, 1997). There were no discussions about mandated scavenger use which could have influenced studies after 1977.

Regardless of controversial effects of trace anesthetic gases, NIOSH (1977) mandates the standards. NIOSH set a ceiling limit for halogenated agents of two parts per million (ppm) for a sampling period of one hour. When halogenated agents are used in combination with nitrous oxide, this combination will result in halogenated levels of approximately 0.5 ppm. Trace anesthetic gases are released into the ambient air with each breath the patient exhales (Huffman, 1996). The waste gas problem for PACU is multiplied by a continuous stream of patients exhaling numerous gases in one room. Several studies have found higher levels (above NIOSH standards) of waste anesthetic gases in the PACU than in the OR (Allen & Badgwell, 1996; Moore, Wehmeyer, Walton, & Badgwell, 1996; Nikki, Pfaffli, & Ahlman, 1972; Nikki, Pfaffli, Ahlman, & Ralli, 1972; Pfaffli et al., 1972; Wehmeyer, Moore, Walton, & Badgwell, 1996). In some cases, these levels exceeded NIOSH standards by seven times the allowable limit (Pfaffli et al., 1972).

PACU nurses work within 12-24 inches of patients' mouths - an area with the highest concentration of waste anesthetic gases. According to NIOSH (1977), the sampling site must be "representative of the concentrations at which workers are exposed during routine procedures ... or shall be representative of the breathing zone of the exposed workers" (p. 6). Austin and Austin (1996) demonstrated that health care workers inhale an inward flow from a distance of 12 inches. Additionally, Badgwell (1997) stated PACU caregivers work in close proximity to the patients' airways during cough inducing procedures, which are often conducted while patients are exhaling fairly high concentrations of waste anesthetic gases.

Allen and Badgwell (1996) demonstrated that patients exhale high concentrations of anesthetic gases even beyond their PACU stay. This fact, coupled with PACU nurses working in areas of high concentrations without scavenger devices, may produce an overall hazardous environment. Nikki, Pfaffli, and Ahlman (1972) reported residual Halothane levels in blood and on the exhaled breath of PACU workers after a six hour shift in the PACU environment.

Badgwell (1997) conducted a study utilizing a new source control system in PACU. He measured isoflurane and nitrous oxide levels to determine the efficacy of this new PACU scavenger. This PACU air source control system significantly lowered concentrations of isoflurane and nitrous oxide below NIOSH standards. However, there are limitations to this air source control system.

Since the exposure limits of trace anesthetic gases were recommended by NIOSH in 1977, new anesthetic agents have been developed and are currently in use. Badgwell (1996) emphasizes that new halogenated agents such as Sevoflurane and Desflurane have a limited resume regarding possible toxicity from chronic occupational exposure. Theoretically,

Sevoflurane and Desflurane should have a lower risk of being an occupational hazard.

These new agents require less biotransformation before elimination when compared with older anesthetics such as Halothane. Kharasch (1995) studied the extent of Sevoflurane metabolism (2-5%) which is less than other volatile agents excluding isoflurane and Desflurane. Nathanson, Fredman, Smith, and White (1995) state there is no difference in recovery periods between Sevoflurane and Desflurane when used for outpatient anesthesia. Expedient recoveries for both Sevoflurane and Desflurane limit exposure time of anesthetic off-gasing in PACU.

Chung and Lam (1997) cite isoflurane as the most popular inhalation anesthetic. But exhaled isoflurane concentrations in PACU can escalate and exceed NIOSH standards (Wehmeyer et al., 1996). This may also be true of Sevoflurane.

Purpose of the Study

Historic and recent studies have demonstrated trace anesthetic gases in PACU that grossly exceed the allowable standards set by NIOSH. Data exists about hazardous PACU environments yet, further research in PACU is necessary.

The purpose of this study is to measure concentrations of Sevoflurane in the recovery room. Specifically, measuring that portion of air which constitutes the PACU workers breathing space. The data collected represents the anesthetic waste gas of Sevoflurane present in the breathing zone of recovery room nurses at David Grant Medical Center, Travis AFB, CA.

Research Question

Do Sevoflurane levels in a PACU exceed NIOSH standards?

The accumulation of anesthetic waste gases in PACU depends on the rate and amount of anesthetic exhaled by the patient. Variables that influence the rate and concentration of anesthetic off-gassing include: patient's weight (obesity), age (number of children), duration of the surgery, number of MAC hours (minimum alveolar concentration or volatile agent times the number of hours), the patient's respiratory rate and the time from discontinuation of anesthetic until monitoring in recovery room. An important factor that influences the severity of the occupational exposure is the length of time an individual is exposed to a hazardous environment. Therefore, the number of hours the PACU worker is exposed will determine the severity of harmful effects.

Theoretical Framework

The hazards in PACU have been of concern enough that NIOSH has regulated trace anesthetic levels. Sister Callista Roy's Adaptation Model best explains the PACU environment shared by the patient and nurse. Roy's model consists of an input (stimuli adaptation level), which causes control processes of coping mechanisms (regulator and cognitive processes) to respond to the stimuli. A regulator responds to stimuli through neural, chemical, and endocrine processes. The cognator responds through thought processes including perception, learning, judgment and emotion. These control processes produce effects which are manifested through four modes: physiological, self concept, role performance, and interdependence. The total effect is termed an adaptive or ineffective response to the initial stimulus (Blue et al., 1994).

In the patient undergoing anesthesia for an operation, anesthesiologists essentially manipulate the environment to affect the adaptive response of the patient. For example, through anesthetic induction or creating a deepened state of anesthesia, the anesthesiologist

manipulates how much anesthetic agent is delivered to the patient. The input stimuli is the anesthetic gas along with intravenous induction, analgesic and neuromuscular blocking agents. These stimuli on the patient are centrally processed along with other inputs such as pain. The regulator, which consists of neuronal and chemical receptors, is saturated with anesthetic agents. The cognator is also affected by anesthetic agents and alters the patient's perception. The patient may perceive relaxation and decreased anxiety which produce a psychomotor response. The effects of processing are also demonstrated through physiological bodily functions. With anesthetics, the patient experiences increased relaxation (sleep), decreased respirations, and decreased temperature. The effect through self concept is the patient's psychological state of mind which directs his/her behavior. This can be a jovial disposition, fear, or confusion but will result in decreased awareness or fading level of consciousness. The patients' role functions remain the same, however, the expression of the role is decreased as awareness of surroundings dissipate. At this point, patients become totally dependent upon the anesthetist. The adaptive response to anesthesia is a deepened anesthetic state.

Once the surgery is completed, the anesthetist manipulates the surrounding environment by turning off and eliminating anesthetic gas exposure. The adaptive response is increased awareness and an awakened state. The stimuli are eliminated; regulator mechanism has decreased saturation levels of anesthetic gas agents; decreasing effects of anesthesia on the cognator mechanism produce increased awareness. Effectors are expressed as: physiological function including return of spontaneous respirations "off-gasing"; self concept increases with levels of consciousness; role function returns with increased levels of awareness along with recall of other roles such as a family member; and a growing

interdependence exists between patient, anesthetist and PACU nurse. The adaptive response is an increased awareness. A byproduct of increased awareness is anesthetic gas released with each breath the patient exhales into the ambient air.

When two systems interact (patient and nurse) they are both influenced by the stimuli within the surrounding environment. Each may adapt differently producing an adaptive response instead of an ineffective response or vice versa. In this case, the output from the patient (anesthetic gas waste) is the input stimuli affecting the PACU nurse, who is also an adaptive system. In the PACU, "recovering patients initially expired up to 700,000 ppm nitrous oxide" (Austin & Austin, 1996, p. 265). The gas levels of recovering patients decrease with each exhalation. However, the expired gas levels remain high for the majority of the PACU stay. These levels far exceed the NIOSH recommendations of 25 ppm. The direct flow of anesthesia gas expired from the patient's lungs is a hazardous area, yet the PACU nurse's role is vigilant maintenance of the patient's airway.

The stimuli to PACU nurses are the exhaled anesthetic gases; that are centrally processed via the regulator affecting the neuronal, chemical, or endocrine processes. The cognator is the perception of the hazard through awareness of occupational risks. The effectors are physiological which may produce acute symptoms of headache, reduced concentration, dizziness, or fatigue. Bruce and Bach (1975) reported that trace anesthetic gases may interfere with optimum performance on perceptual, cognitive and motor skills. Sweeney, Bingham, Amos, Petty, and Cole (1985) provide evidence that direct exposure to nitrous oxide may cause depression of vitamin B12 and chronic low level exposure inhibits methionine synthase which impairs synthesis of deoxyribonucleic acid and bone marrow function.

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Self concept is the perception of the nurse in a safe working environment. The role of the PACU nurse involves maintenance of the patient's airway. Interdependence of the nurse involves reliance on employer/staff maintenance of NIOSH standards. The culminating effects of high level gas exposure have been linked to ineffective responses in PACU nurses such as miscarriage and congenital abnormalities. These are "responses that do not contribute to adaptive goals, that is, survival, growth, reproduction, and mastery" (Blue et al., p. 248). Rowland et al. (1992) found that occupational exposure to high levels of nitrous oxide may adversely affect fertility in women.

The Roy Adaptation Model (1981) can effectively describe anesthesia stimuli and its adaptive responses within the patient and the PACU caregivers. As anesthesia is exhaled by the patient, it manifests itself as a hazardous stimulus to the PACU nurse which may result in an ineffective response.

Definitions: Conceptual and Operational

This study concentrated on the focal stimuli which may contribute to the controversial maladaptive effects of trace anesthetic gases. Other stimuli are defined but not measured.

System

A set of units related to one another. Relationships are established among the units (Roy & Roberts, 1981).

Adaptation

A process done by living systems when interacting with their environment (Roy & Roberts, 1981).

Adaptation level

The pooled effect of focal, contextual, and residual stimuli. It is a constant flux which represents the range of stimuli the individual will tolerate and results in normal adaptive responses (Roy & Roberts, 1981).

Focal stimuli.

Conceptual definition. The focal stimuli forces the person to make an adaptive response (Roy & Roberts, 1981). It is the factor that elicits the behavior (Blue et. al., 1994).

Operational definition.

1. Sevoflurane levels - levels of Sevoflurane obtained from the breathing zone of PACU nurses at Travis AFB, 6 and 7 October, 1998..

2. NIOSH Standard - less than or equal to 2.0 ppm. Sevoflurane was not combined with nitrous oxide during this study. Therefore, the ceiling limit will be 2.0 ppm instead of 0.5.

Contextual stimuli

Conceptual definition. Contextual stimuli include all other stimuli present surrounding the situation which contributes to the adaptive behavior (Blue et. al., 1994).

Operational definition. The milieu of noise, distractions, sensory overload, and stress comprise the contextual stimuli of PACU.

Residual stimuli

Conceptual definition. Residual stimuli contribute to the focal stimuli but cannot be validated or measured. These include beliefs, experience, attitudes or traits (Roy & Roberts, 1981).

Operational definition. Operationally, residual stimuli encompass all of the following: PACU caregivers attitudes towards trace anesthetic gases; their beliefs concerning whether PACU is a hazardous environment or not; detrimental or positive experiences working within the PACU environment.

Adaptive responses

Conceptual definition. Adaptive responses promote a person's goals of survival, reproduction, growth, and mastery (Blue et. al., 1994).

Ineffective responses

Conceptual definition. Ineffective responses do not contribute to adaptive responses and goals (Blue et. al., 1994).

Assumptions

The following assumptions pertain to PACU caregivers, the daily operations of a PACU, and incorporate fluctuations in the hourly census of PACU.

1. PACU caregivers do not wish to be exposed to high levels of anesthetic gases.
2. Anesthetic waste gases in PACU will vary due to ventilation exchange rates in PACU, concentrations exhaled by patients, and the maximum number of patients exhaling anesthetic gases simultaneously in PACU.
3. Personnel involved in the sampling will care for patients who have had a general anesthetic with Sevoflurane.

Limitations

This was a descriptive, correlational study of one PACU. Results may not be generalized to other PACUs and no causal relationships are suggested.

Summary

The problem of waste anesthetic gases remains controversial, and warrants further study. A newer halogenated agent such as Sevoflurane requires closer review to determine if it creates a hazardous environment in PACU. This study measured Sevoflurane concentrations in PACU to describe effects of this gas in the PACU environment.

CHAPTER TWO LITERATURE REVIEW

Controversial Background

The controversy continues of whether trace anesthetic gases are hazardous to our health or not. The controversy involves anesthetic gases causing spontaneous abortions, adverse reproductive effects, cancer, neurological, renal and liver disease. Several studies have indicated a correlation, but other studies dispute these claims. This chapter will present both sides of the issue, review NIOSH standards, explain anesthetic waste gases and their problem in PACU, review proposed scavenger devices in PACU, and explain the characteristics and pharmacokinetics of Sevoflurane.

Harmful Effects

The American Society of Anesthesiologists, Ad Hoc Committee on the Effect of Trace Anesthetics on the Health Of Operating Room Personnel (Ad Hoc Committee)(1974), conducted a study that mailed questionnaires to 49,585 exposed operating room personnel and to 23,911 unexposed individuals. Results indicated that female members in the operating room had increased risks of spontaneous abortion, congenital abnormalities in their children, cancer, hepatic and renal disease. This study did not establish a cause and effect relationship but coupled with animal studies it was reasonable to assume that potential health hazards existed for personnel exposed to anesthetic waste gases. The Ad Hoc Committee strongly recommended venting waste anesthetic gases in all anesthetizing locations.

Sweeney, Bingham, Amos, Petty, and Cole (1985) monitored 21 dentists who routinely used nitrous oxide. The bone marrows of these 21 dentists were studied under

the influence of nitrous oxide exposure. The mean exposure to nitrous oxide ranged from 159 to 4600 ppm. The bone marrow aspirate was examined by the deoxyuridine suppression test which objectively measured synthesis of DNA dependent on vitamin B12 and folic acid. Abnormal deoxyuridine suppression tests resulted from three of the 21 dentists. This study was the first to provide direct evidence that occupational exposure to nitrous oxide may cause decreased vitamin B12 function which impaired DNA synthesis.

Guirguis, Pelmeur, Roy, and Wong (1990) conducted a retrospective study by questionnaire to 8032 personnel exposed to anesthetic gases in OR's and recovery rooms and to 2525 non exposed hospital staff. They demonstrated that women in the exposed group as well as spouses of men in the exposed group had significantly higher incidences of spontaneous abortions and congenital abnormalities. Comparison of their results with other studies, along with acknowledging the limitation of questionnaire studies, led to the conclusion that the consistency of these findings rendered emphasis on minimizing the circulation of anesthetic gases in operating and recovery rooms.

Rowland et al. (1992) interviewed 459 female dental assistants between the ages of 18 and 39. They found that women exposed to nitrous oxide for more than five hours a week were significantly less fertile than women who were unexposed or exposed to lower levels of nitrous oxide.

These studies did not go unrecognized. The National Institute for Occupational Safety and Health (NIOSH) (1994) and the Center for Disease Control (CDC) issued a joint ALERT bulletin that states:

Data from animal studies demonstrate that exposure to N₂O may cause adverse reproductive effects. Studies of workers exposed to N₂O have reported adverse

health effects such as reduced fertility, spontaneous abortion, and neurological, renal and liver disease. The recommendations in this Alert should therefore be followed to minimize worker exposures. (p. 3)

Harmless Effects

Despite multiple studies indicating that anesthetic waste gases are hazardous, a few studies dispute these claims. Ericson and Kallen (1979) based their study on the outcome of deliveries between 1973 and 1975 of women working during their pregnancies in the operating room. The study group was compared to a reference population of all women employed in medical work in Sweeden and who had deliveries during 1973 and 1975. No differences in the incidence of threatened abortions, birth weight, perinatal death rate or congenital malformations were found. The only suggested difference was an increased incidence of pregnancies lasting less than 37 weeks. Erikson and Kallen cited that this negative outcome has the same varience as all other published investigations. They stated that collection of data by interviews or mailed questionnaires to women who were fully aware of the dangers of volatile anesthetics, can only compromise results and produce biased outcomes. Ericson and Kallen claim that findings reported in the literature regarding reproductive hazards by volatile anesthetics are skewed by biased data collection.

Hemminki, Kyyronen, and Lindbohn (1985) reported no significant increases in spontaneous abortions or malformations in pregnant operating room workers after exposure to waste anesthetic gases. They used the Hospital Discharge Register and the Register of Congenital Malformations in Findland to select nurses with spontaneous abortions or a malformed child during 1973 to 1979. There were 217 nurses with spontaneous abortions

and 46 nurses with a malformed child. Information on exposure during the first trimester of pregnancy was collected through questionnaires sent to the head nurses of the hospitals. There was no significant increase in risk of spontaneous abortion or of malformation after exposure to anesthetic gases. An additional fact was mentioned. There appeared to be no decreasing trend in spontaneous abortions in the 1970s when attempts to reduce anesthetic waste gases in operating rooms were made all over Finland.

Tannenbaum and Goldberg (1985) reviewed the epidemiologic literature and determined that due to significant flaws in design and conduct of the observational studies, there was insufficient evidence to support that occupational exposure to anesthetic agents caused increased spontaneous abortion or congenital anomalies. Their criticisms were based on varied methodology, retrospective data collection (bias recall), different populations studied, reliability of outcome data and low response rates. They recommend prospective studies to determine if trace anesthetics are truly harmful in the workplace.

NIOSH Standards

The recommendations of NIOSH (1977) state that no worker should be exposed to any halogenated anesthetic agent above a ceiling concentration of 2 ppm. For halogenated agents mixed with nitrous oxide, the standard is 0.5 ppm. The nitrous oxide standard is 25 ppm based on a time weighted average. These standards apply "to all workers, including students and volunteers, regardless of status, who are exposed to inhalation anesthetic agents that escape into locations associated with the administration or recovery from anesthesia" (p. 3).

The National Institute for Occupational Safety and Health (1977) defines waste inhalation anesthetic gases and vapors as those which escape into work areas. Work areas include operating rooms, recovery rooms, delivery rooms, and any other area where workers

are exposed to waste anesthetic gases. Control of waste anesthetic gases employs the use of scavenger devices on anesthetic delivery systems. In the PACU where scavenging systems are not used, ventilation air exchange rates must be in compliance with the US Department of Health, Education and Welfare.

PACU Exposure Problems

PACU vs OR

Nikki, Pfaffli, Ahlman, and Ralli (1972) measured the impact of waste anesthetic gas concentration levels in the PACU environment. Ambient levels of Halothane and nitrous oxide were measured in three recovery rooms. They found the average concentration of 2.77 ppm for Halothane and 146 ppm for N₂O. The recovery room closest to the ORs had slightly higher concentrations of Halothane and nitrous oxide than the other two recovery rooms which were further away from unscavenged ORs. These levels averaged 2.31 ppm for Halothane and 120 ppm for N₂O. The mean concentration of Halothane in scavenged ORs was 0.85 ppm and nitrous oxide mean was 135 ppm. The average concentration of Halothane in the recovery rooms was three times higher than that in operating rooms with scavenging devices.

Pfaffli, Nikki, and Ahlman (1972 a) measured Halothane and nitrous oxide by gas chromatography in both the operating rooms and recovery rooms. Twenty samples were obtained from the ORs and twenty-two samples were obtained from the recovery rooms. Anesthetic waste gases were eliminated in the ORs, however Halothane and nitrous were higher in the recovery rooms. In the recovery rooms, the mean Halothane concentration was 3.0 ppm and nitrous oxide was 305 ppm (this is 12 times the NIOSH standard). In the scavenged ORs the Halothane mean was 1.7 ppm and nitrous oxide mean was 165 ppm.

Nikki, Pfaffli, and Ahlman (1972 b) conducted end tidal and blood Halothane and nitrous oxide levels on surgical personnel. They measured Halothane in the blood and breath of recovery room personnel before working a four to six hour shift in a PACU with mean concentrations of Halothane 2.9 ppm in the air. No detectable quantities of Halothane were found in the blood or end-tidal air of pre-shift PACU workers. After four to six hours of exposure, measured concentrations of Halothane were 0.10 ppm in exhaled breath and 2.2 ug/100 ml of venous blood. End tidal concentrations of Halothane for PACU workers were higher than for personnel working in a scavenged OR.

Current PACU Levels

Moore, Wehmeyer, Walton, and Badgwell (1996) proposed that there are escalated levels of nitrous oxide in PACU. Nitrous oxide is delivered in concentrations of up to 70% (700,000 ppm) during general anesthesia. Nitrous is highly insoluble and elimination occurs rapidly. Nitrous oxide waste gas is not considered to be a significant waste gas hazard in PACU. Moore et al. quantified nitrous oxide elimination in PACU. Eight patients were given a controlled anesthetic regimen to include fentanyl, thiopental, isoflurane and nitrous oxide. After arrival to the PACU (less than 10 minutes post extubation) nitrous oxide levels were measured using a source control system which allows end tidal measurement of waste anesthetic gases in PACU. One minute and sixty minute intervals were used for sample collection criteria. The average end tidal N₂O at one minute was 43,705 plus or minus 13,190 ppm. At sixty minutes the average N₂O concentration was 14,079 plus or minus 9213 ppm. Patients continued to eliminate N₂O throughout their PACU stay. This study indicates that N₂O is not immediately eliminated and concentration of anesthetic gases are in excess of NIOSH (1977) standards of 25 ppm.

Wehmeyer, Moore, Walton, and Badgwell (1996) measured exhaled isoflurane levels on six patients. Isoflurane is delivered in concentrations up to 2% (20,000 ppm) for general anesthesia. Elimination through the respiratory tract is thought to occur rapidly. Wehmeyer et al. determined decay curves for isoflurane elimination in PACU patients. Six patients were given a controlled anesthesia regimen of fentanyl, thiopental, isoflurane and nitrous oxide. Upon arrival to the PACU (less than 10 minutes post extubation) a source control system was applied to the patient's face which delivered oxygen and scavenged exhaled gases. End tidal concentrations of isoflurane were taken at one minute and sixty minute intervals. At one minute, the mean concentration of isoflurane was 1638 plus or minus 518 ppm. For the sixty minute interval, the mean concentration was 833 plus or minus 93 ppm. Patients eliminated isoflurane throughout their PACU stay. These concentrations exceeded NIOSH standard (0.5 ppm ceiling when a halogenated agent is combined with N₂O) by 1500 times.

According to Allen and Badgwell (1996) studies measured concentrations of anesthetic gases during the elimination process. After five minutes of inhaling 50% nitrous oxide, end tidal measurements yielded excess concentrations of nitrous for over two hours. If 30 minutes of N₂O was inhaled, then four hours were required to decrease N₂O to the NIOSH limit of safety. Each and every patient that inhaled 50% N₂O for one to two hours, exhaled N₂O concentrations that tripled NIOSH safe limits. These excess concentrations were continually exhaled for three hours. Patients may be exhaling excess nitrous oxide levels beyond their PACU stay.

Breathing Zone

Austin and Austin (1996) conducted a study to understand how the concentration of nitrous oxide varies with distance from a recovering patient. In this experiment, a nitrous oxide source of 750 ppm was delivered at a steady rate of 25 ml/min through a half inch diameter tube, simulating the patient's mouth. A sampling probe was placed at 21 inches (location of workspace for a PACU nurse) and at 28 inches. They found that nitrous oxide concentrations decreased with distance; the patients respiration's increased the level of nitrous oxide where the nurse is located (21 inches or 53 cm from the patients mouth); and the nurse's breathing pulls the nitrous oxide inward from the flow field and increases the exposure to the gas.

Allen and Badgwell (1996) state that the PACU environment is essentially an open ward with a diverse patient population. Patients frequently cough and exhale waste anesthesia gases. This open environment provides a network of hazardous risks to both the patient and PACU personnel. Air exchange ventilations do not eliminate the problem. They propose that "a nurse caring for only two patients at a time over several hours would be exposed to a time weighted average concentration in excess of 25 ppm."

Scavenger Devices in PACU

It has been proven that scavenger devices in the OR have reduced the exposure to waste anesthetic gases. Nikki, Pfaffli, Ahlman, and Ralli (1972) verified the effectiveness of scavengers in the OR. Scavengers, along with adherence to NIOSH (1977) control procedures has decreased the level of exposure to one tenth the level of an unscavenged environment.

Badgwell (1997) evaluated the Apotheus Laboratories, new source control system for PACU (Air Care Source Control System). He evaluated the system based on the degree to which the Air Care Source Control System can reduce the amount of waste anesthetic gases released by the patient into the PACU environment. Twenty two post surgical patients were studied. The control group received routine care with supplemental oxygen via nasal cannula. The experimental group received oxygen via the source control system which is a tight fitting face mask with special features to vent anesthetic waste gases. Results concluded that the control group exceeded compliance criteria (isoflurane levels >2.0 ppm or if N_2O concentration > 25 ppm time weighted average) 58% of the time. Whereas, the experimental group never exceeded compliance criteria. These results proved the source control system is effective at reducing waste anesthetic gases in PACU.

Limitations of the source control system include length of time the patient is recovered, efficacy of the mask seal, and functioning oxygen and vacuum systems. The source control system cannot be used for patients who have facial wounds, deformities, or excess facial hair which would compromise the seal of the face mask. There was no mention if any problems occurred with post anesthesia vomiting and a tight fitting mask.

Sevoflurane Characteristics and Pharmacokinetics

Holaday and Smith (1981) state there are two characteristics of a volatile anesthetic molecule that determine the extent of biotransformation. Tissue solubility and chemical stability are the predictors of biotransformation. The low blood - gas and oil - gas coefficients of Sevoflurane favor its rapid excretion from the body. This results in rapid off-gassing, and rapid awakening time. Low tissue solubility would cause most of the

biotransformation (done by the liver) to occur during exposure. The resulting metabolites in blood levels were found to be insignificant..

Kharasch (1995) studied the biotransformation of Sevoflurane. Sevoflurane is biotransformed into organic and inorganic fluoride metabolites. Sevoflurane is oxidized by the cytochrome P-450 2E1 enzymes in the liver. Inhibition of the P450 2E1 enzymes by disulfuram (antabuse) will decrease Sevoflurane metabolism. Acute ethanol use will also inhibit P450 2E1. Induction of P450 2E1 enzymes will increase the metabolism of Sevoflurane. Factors that increase Sevoflurane metabolism include: obesity, isoniazid, prolonged fasting, chronic ethanol use, and untreated diabetes. Obese patients with fatty liver infiltration have higher P450 2E1 enzyme content and greater rates of anesthetic metabolism. Phenobarbital, phenytoin and treated diabetes have no effect on the metabolism of Sevoflurane.

The extent of Sevoflurane metabolism is 2 - 5%. The small amount of organic and inorganic metabolites are inactive. Cytochrome P450 enzymes catalyze Sevoflurane to a transient intermediate which decomposes to an inorganic fluoride ion and the organic fluoride metabolite hexafluoroisopropanol (HFIP). Both these metabolites are formed in equal amounts. HFIP is further conjugated with glucuronide which makes it more water soluble for excretion by the kidneys. The limited and rapid biotransformation makes it an excellent anesthetic for quick induction and rapid recovery.

Yasuda et al. (1991) measured uptake and recovery time of Sevoflurane and isoflurane on seven male volunteers with a mean age of 23 and a mean body weight of 72 Kg. Their results showed that Sevoflurane has a more rapid uptake than isoflurane. This correlates with Sevoflurane's lower blood gas solubility. Since Sevoflurane enters the body more rapidly it

is presumed to leave more rapidly than isoflurane. However, their study found that the elimination from the tissues did not differ between Sevoflurane and isoflurane. Also, the metabolism of Sevoflurane did not differ from the estimated metabolism of isoflurane.

When comparing blood - gas solubilities, Sevoflurane has a lower solubility and the advantage over isoflurane. Although Sevoflurane and isoflurane have different blood gas coefficients which are used as a predictor of uptake and elimination from the body, they still have similar elimination time constants from the body. Yasuda et al. emphasizes there is overestimation with the blood - gas solubilities. The tissue-blood partition coefficient of Sevoflurane is slightly greater than isoflurane. Hence, here lies the answer for Sevoflurane and isoflurane having the same recovery time yet different blood-gas coefficients. Since Sevoflurane and isoflurane are so similar in their recovery times, Sevoflurane levels in PACU could equate to isoflurane levels in PACU.

Conclusion

The controversy of adverse health problems associated with anesthetic waste gases continues. Although the debate goes on, there are more studies indicating a correlation or weak relationship than studies with negative findings about adverse health problems associated with trace anesthetic gases. Studies from 1970's to the 1990's continue to provide suggestive evidence regarding ill health and prolonged exposure to anesthetic gases. The National Institute for Occupational Safety and Health has determined standards to follow regarding trace anesthetic waste gases. The current question now is if these standards are met in PACU's. With a new halogenated agent such as Sevoflurane, PACU levels need to be explored. Sevoflurane does not been as well investigated in PACUs as Halothane, isoflurane,

or nitrous oxide. Further studies are necessary to determine if NIOSH standards are being met.

CHAPTER THREE METHODS

Research Design and Procedure

This descriptive study measured the exposure of recovery room nurses to Sevoflurane. The recovery room nurses monitored, only cared for patients who had been anesthetized with Sevoflurane. This measured the maximum exposure that a recovery room nurse would have to Sevoflurane when administering routine post operative care. Measurements of Sevoflurane levels were taken during two days when Sevoflurane was used the most at Travis AFB. Sequential air samples from PACU nurses' breathing space were taken. Air samples ranged from 88 minutes to 120 minutes. The sampling periods included early in the morning, late in the morning, and early in the afternoon on 6 and 7 October, 1998. One additional late afternoon sample was taken on the second sampling day.

Sample

All PACU nurses were briefed about the study. Volunteers were recruited in a similar way to standard protocol measuring nitrous oxide, halothane, or isoflurane. The sample included PACU nurses working day shifts, who were assigned to patients only anesthetized with Sevoflurane. The purpose of the study was to describe and measure Sevoflurane exposure that recovery room nurses would have while caring for post operative patients. Two recovery room nurses were randomly selected and were assigned to care for Sevoflurane patients only. The early dayshift nurse scheduled for 6 October and 7 October was selected to participate in the study.

Measurement

Variable of Interest

The variable of interest is Sevoflurane levels in PACUs. Sevoflurane levels were monitored by bioenvironmental health at Travis, AFB according to their standard protocol.

Other Variables of Interest

Variables were documented by the nurse anesthetist and the PACU nurse during the sample collection.

1. The number of patients who has received a Sevoflurane anesthetic that the recovery room nurse cared for during the monitoring period. This was documented by the recovery room nurse during the measuring period.

2. Number of MAC hours of Sevoflurane patients. MAC hours is the minimum alveolar concentration of the volatile agent times the number of hours the anesthetic was delivered. This was calculated by the primary investigator from the anesthetic record.

3. Respiratory rates of patients assigned to the recovery room nurse. This was monitored and recorded on the vital sign record in the PACU.

4. Age of the patients assigned to the recovery room nurse was annotated on the anesthetic record.

5. Patients weight and body mass index (BMI). According to Victoria Base-Smith (1997), the body mass index is the most useful assessment tool for determining weight. It approximates the percentage of fat relative to the patient's height. The formula for BMI is weight in kilograms divided by height in meters squared. Non obesity mean values represent 20 - 25 Kg/m², mild obesity (grade I) is 26 - 29 Kg/m², moderate obesity (grade

II) is 30 - 35 Kg/m², and morbid obesity (grade III) is defined as a BMI greater than 35 Kg/m². This was calculated by the primary investigator from the anesthetic record.

6. The time from discontinuation of Sevoflurane until patients entered monitoring in the PACU was recorded on the anesthetic record. This is the time period where most of the "off loading" of anesthetic occurs and may affect Sevoflurane levels in PACU.

The recovery room personnel involved in sampling wore an Ametek (Alpha 2) pump throughout the work day. The pump was calibrated using the Gilian Gilibrator-2 primary flow calibrator. The Ametek pump is a typical air sampling pump for estimating amounts of forane or halothane in PACU. The set up incorporates two charcoal tubes that absorb anesthetic gases when ambient airflow is pumped through the system. These charcoal tubes are coconut based media tubes from SKC Inc. (SKC Lot 120 NIOSH approved cat #226-01).

The procedure involved collection of samples (anesthetic waste gas) by drawing a known volume of air through charcoal tubes. Sample collection ports were placed on the shoulder of the recovery room nurse to ensure sampling of the nurse's breathing space. According to Michael Shulsky (1984), the recommended air volume and sampling rate is 3L at 0.2 L/min. The personal sample pump was calibrated within plus or minus 5% of this recommended flow rate. SKC coconut shell charcoal tubes lot #120 are OSHA approved and has been utilized by the Methods Evaluation Branch, OSHA Laboratories. Coconut shell tubes consist of glass tubes 7 cm long, 6 mm o.d. (outer diameter) and 4mm i.d. (internal diameter). They contain a 100 mg section of charcoal and a 50 mg section of charcoal separated by a urethane foam plug. The glass tube is flame sealed at both ends.

All tubes were from the same lot of charcoal. Immediately before sampling, the tubes were opened at both ends and connected to the pump with a short piece of flexible tubing by the bioenvironmental technician. Eye protection was worn when breaking the ends of the charcoal tubes. Since the 50 mg portion is used as the back up section, the air must flow through the 100 mg charcoal portion first. The tubes are positioned vertically. Air sampled did not pass through any hose or tubing before entering the charcoal tube. The temperature and relative humidity of the atmosphere being sampled was recorded. The sampling pump was placed on the recovery room nurse and did not interfere with the performance of duties. The charcoal tubes were placed in a holder so broken ends are not exposed.

Immediately after sampling, the ends of the tube were sealed with plastic caps. One blank charcoal tube from the same lot with no air drawn through it served as the control. According to standard protocol, along with the sample set, Sevoflurane was placed in glass bottles with Teflon lined caps and transported to the laboratory separately from the air samples. All samples were federal expressed the next day to Armstrong Laboratories.

The gas chromatography was performed using the carbon disulfide reagent which desorbs Sevoflurane from the charcoal. CTCT-101 is a general chromatographic analysis - carbon disulfide (101) According to Rudling and Bjorkholm (1986), carbon disulfide desorbing agent is widely used because of its ability to desorb non polar compounds, and its low response on the flame ionization detector during gas chromatography.

Method of Sampling/Validity and Reliability

Desorption efficiency is a measure of how much anesthetic agent (absorbed on the charcoal) can be recovered. SKC (coconut shell charcoal) desorption efficiency data for aliphatic compounds demonstrate a recovery range from 94% - 100%. According to Shulsky (1984), the method and procedure for petroleum distillate fraction (PDF) samples collected by drawing a known volume of air through charcoal SKC tubes, desorbed by carbon disulfide, and analyzed by gas chromatography can yield reliable results of 100% recovery of PDF. If samples were stored for a period of 19 days, 96% recovery was achieved with ambient temperature storage, and 97% achieved with refrigerated samples. The method and procedure for gas chromatography with carbon disulfide reagent has been extensively evaluated and approved by the Organic Methods Evaluation Branch of OSHA Analytical Laboratories, Salt Lake City Utah (Shulsky, 1984).

High humidity can cause pore blocking on the charcoal surface and decrease the sampling capacity. Rudling and Bjorkholm (1986) demonstrated that a relative humidity of 80% reduced recovery of organic compounds. They concluded that water vapors adsorbed can change the desorption efficiency for water soluble compounds if carbon disulfide is used as the desorbing reagent. The surface of the carbon is also affected by the accumulation of water. In this case, the use of a desorbing agent which is capable of dissolving water will eliminate the problem.

Protection of Human Rights

Measurement of anesthetic waste levels in PACU is necessary for the health and welfare of all PACU workers. This protocol is used at USAF Medical Facilities with recovery rooms. The only apparent risk involved is not measuring anesthetic waste levels

in the work environment. To ensure safety, anesthetic waste levels must be measured, specifically in the breathing zone of the PACU caregiver. Any day shift nurse who volunteered for sampling and was assigned Sevoflurane patients in the recovery room.

Plan for Data Analysis

Upon receiving results of Sevoflurane levels from Armstrong Laboratories at Brooks, AFB, sample statistics of all variables of interest were provided. These included Sevoflurane levels in ppm, the number of patients cared for by the recovery room nurse, number of MAC hours, respiratory rates, ages, and body mass indexes. For each sample set, the resulting Sevoflurane level is described and explained relating to the corresponding values for other variables of interest in Appendix C.

CHAPTER FOUR

PRESENTATION, ANALYSIS AND INTERPRETATION OF DATA

In this descriptive study, Sevoflurane levels in PACU were measured and found to be within NIOSH standards. Air samples taken from PACU nurses' breathing space had Sevoflurane levels less than 2.0 ppm. The sequential samples when collected included early in the morning, late in the morning, and early in the afternoon on 6 and 7 October, 1998. One additional late afternoon sample was taken. The selected days were when Sevoflurane was used the most at Travis AFB which included children having ear, nose, and throat surgeries.

Variable of Interest

All levels of Sevoflurane were within the NIOSH standard of 2.0 ppm. Values for Sevoflurane samples ranged from .07 ppm to .83 ppm (Tables 1 and 2) (mean = .27 ppm). Discussion of values outside of the mean are presented later in this chapter.

Other Variables of Interest

In this study the age of patients who received Sevoflurane ranged from 13 months to 71 years (mean 39.3 years). There were six females and two males.

Patients' weights ranged from 12 to 86 Kilograms (Kg) (mean 55.7 Kg). Patients' weights and body mass indexes (BMI) were calculated. The BMI ranged from 21.4 (Kg)/meters squared (m²) to 33 Kg/m². The mean BMI was 26.9 Kg/m². One body mass index could not be calculated (due to insufficient data).

The time from discontinuation of Sevoflurane until patients entered monitoring areas in the PACU was recorded. On the first sampling day, the average time from discontinuation of anesthetic until beginning of PACU monitoring was 11 minutes.

Sevoflurane Data

<u>Air Samples</u> 6 Oct 98	<u>Variable</u> <u>of</u> <u>Interest</u>	<u>Other Variables of</u> <u>Interest:</u> Sevo Patients in PACU	<u>Other Variables of Interest:</u> Patient Data	
#FZ980340 Time collected: 0750 - 0918 (88 min)	.24 ppm	1 patient 0750 - 0815	Age: 13mo	Wt: 12 Kg
			Gender: F	BMI: 21.4
			Avg RR: 26	Mac Hrs: .75
			Time Sevo off until pt entered PACU = 10 min	
		1 patient 0810 - 0845	Age: 4yo	Wt: 20.5Kg
			Gender: F	BMI: *ND
			Avg RR: 22	MacHrs: .825
		*RN took care of 2 Sevo patients for 5 min	Time Sevo off until pt entered PACU = 5 min	
#FZ980341 Time Collected: 0920-1048 (88 min)	.23 ppm	1 patient 0900-0945	Age: 58 yo	Wt: 86Kg
			Gender: M	BMI 29
			AvgRR: 16.8	MacHrs: .18
			Time Sevo off until pt entered PACU = 10 min	
#FZ980342 Time collected: 1050 - 1305 (135 min)	.14 ppm	1 patient 1025 - 1120	Age: 19yo	Wt: 61Kg
			Gender: M	BMI: 27
			AvgRR: 18	Macrs: .85
			Time Sevo off until pt entered PACU = 20 min	
		1 patient 1135 - 1225	Age: 64yo	Wt: 56Kg
			Gender: F	BMI: 27
			AvgRR: 20	MacHrs: 1.4
			Time Sevo off until pt entered PACU = 10 min	

PACU = Post Anesthetic Care Unit; Sevo = Sevoflurane; min = minutes; pt = patient; AvgRR = Average Respiratory Rate; Mac Hrs = Mac Hours which is the average Sevoflurane concentration multiplied by the number of hours the anesthetic was delivered; *ND = no data available such as height to calculate BMI.

Table 1**6 Oct 1998 Sevoflurane Levels in PACU**

Sevoflurane Data

<u>Air Samples</u> 7 Oct 98	<u>Variable of Interest</u>	<u>Other Variables of Interest:</u> Sevo Patients in PACU	<u>Other Variables of Interest:</u> Patient Data	
#FZ980349 Time Collected: 0823-0953 (90 min)	.09ppm	No Sevo patients in PACU		
#FZ980350 Time Collected: 0954-1140 (106 min)	.31ppm	1 patient 1005-1125	Age: 71yo Gender: F AvgRR: 20 Time Sevo off until pt entered PACU = 5 min	Wt: 67K g BMI: 26 MacHrs: 1.88
#FZ980351 Time Collected: 1141-1339 (118min)	.07ppm	No sevo patients in PACU		
#FZ980352 Time Collected: 1340-1540 (120 min)	.83ppm	1 patient 1350-1540 1 patient 1455-1540 * RN took care of 2 Sevo pts for 45 min	Age: 44yo Gender: F AvgRR: 21.5 Time Sevo off until pt entered PACU = 15 min	Wt: 76K g BMI: 33 MacHrs: 7.08
			Age: 53yo Gender: F AvgRR: 18 Time Sevo off until pt entered PACU = 10 min	Wt: 67K g BMI: 25 MacHrs: 7.4

PACU = Post Anesthetic Care Unit; Sevo = Sevoflurane; min = minutes; pt = patient; AvgRR = Average Respiratory Rate; Mac Hrs = Mac Hours which is the average Sevoflurane concentration multiplied by the number of hours the anesthetic was delivered.

Table 2

7 Oct 1998 Sevoflurane Levels in PACU

On the second day of sampling, the average time was ten minutes. This is the period of time when most of the gas "off-loading" occurs and may affect Sevoflurane levels in PACU, however, no differences in ambient Sevoflurane levels were found.

The respiratory rates of patients in the PACU who had received Sevoflurane ranged from 16.8 to 26 breaths per minute (BPM) (mean 20.3 BPM). The mean respiratory rate of patients during the first day of sampling was 20.5 BPM and on the second day the mean was 19.8 BPM.

The variable "MAC hours of Sevoflurane" was calculated as the average end-tidal Sevoflurane concentration in the operating room multiplied by the number of hours the anesthetic was delivered. The range was .18 to 7.4 MAC hours, (mean 2.54). The highest MAC hours (7.08 and 7.4) occurred during the air sampling period which yielded the highest ambient Sevoflurane levels (.83 ppm of Sevoflurane).

The number of patients who receive a Sevoflurane anesthetic that PACU nurses care for during a sampling period could affect the level of Sevoflurane detected. On the first sampling day, only one patient who had received Sevoflurane occupied the PACU at any given time. One exception was in the early morning sampling period of the first day of sampling when the PACU nurse cared for two patients concurrently who had received Sevoflurane. She was exposed to the two patients for a total of five minutes.

On the second sampling day, there were sampling periods in which no patients who had received Sevoflurane were in PACU. Air samples taken during this time (90 min and 118 min) had Sevoflurane levels of .09 ppm and .07 ppm. Later that day, the PACU nurse concurrently cared for two patients who had received Sevoflurane. The corresponding air

sample in this time was .83 ppm of Sevoflurane. This was also during a time when the nurse was caring for patients with the highest MAC hours of Sevoflurane.

Interpretation of Data

Data is displayed in Figure 1. Three samples were collected on 6 October, 1998 in

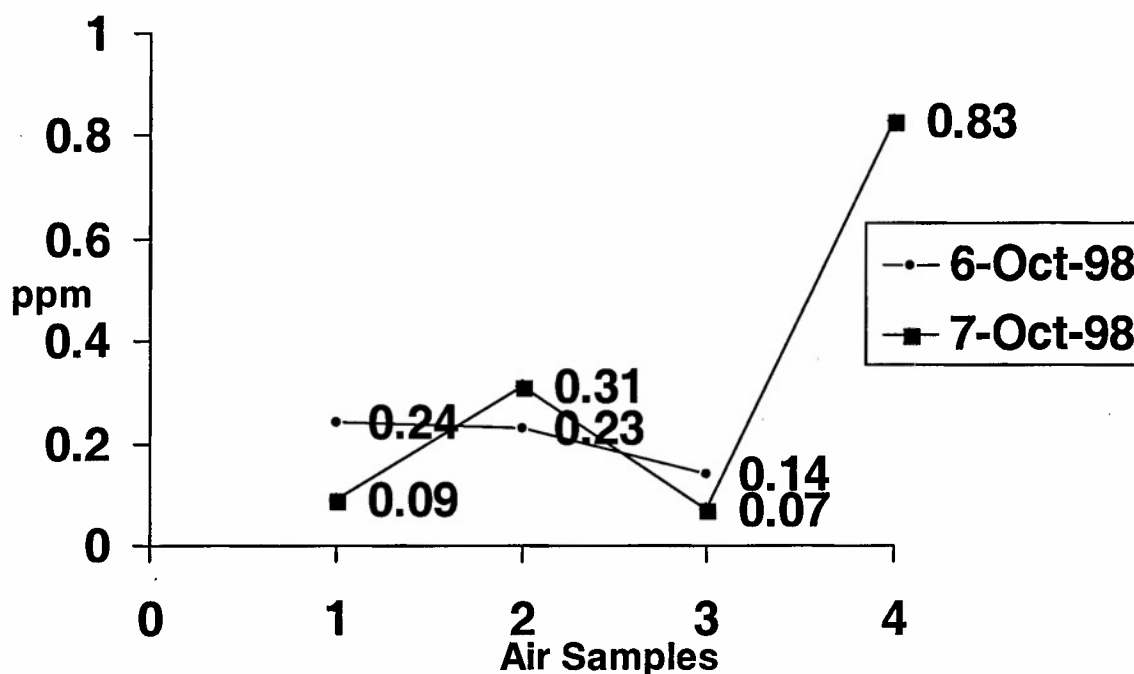


Figure 1

Sevoflurane Data

early morning, late morning and late afternoon. They were sent to the 311th HSW IERA/SDC at Brooks AFB for analysis. The samples contained .24, .31, and .14 ppm of Sevoflurane respectively. Four samples were collected 7 October, 1998 in early morning, late morning, early afternoon, and late afternoon, and these samples contained .09, .31, .07, and .83 ppm of Sevoflurane respectively. The mean level of Sevoflurane in the air samples from both days was .27 ppm (SD .26 ppm).

As expected, the lowest values for Sevoflurane were obtained when there were no patients in PACU who had received Sevoflurane. On 7 October, 1998, there were two sampling periods where there were no patients in PACU who had Sevoflurane - the early am and the early afternoon sampling periods. However, later in the day, the recorded level was .83 ppm. It is interesting that this corresponded to the time when the PACU nurse cared for two patients in PACU who had very long MAC hours (7.08 and 7.4) of Sevoflurane.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

Historic as well as more recent studies continue to demonstrate that trace anesthetic gases are present in PACUs. In this study the breathing space of PACU workers was measured to determine Sevoflurane levels in PACU. All PACU personnel were briefed about the study and all volunteered to participate. Two were randomly selected. The nurses scheduled to work the early shift on 6 October 1998 and 7 October 1998 were chosen to participate. The PACU nurses' breathing space was then continuously monitored throughout their work day. Sequential air samples were taken by bioenvironmental health at Travis AFB, CA. Upon completion of data collection, exposed SKC charcoal tubes were sent to the 311th HSW IERA/SDA at Brooks AFB for analysis by gas chromatography. Results of Sevoflurane levels in ppm for each sample were below NIOSH (1977) standard of 2.0 ppm.

Conclusions

The elevated levels of trace Sevoflurane in PACU (.83 ppm) on the second data collection day, may be related to the fact that PACU nurse was caring for two patients with Sevoflurane concurrently for forty-five minutes. In addition to the overlap of patients, both patients had higher MAC hours of Sevoflurane. The increased MAC hours may have elevated Sevoflurane exposure to the PACU nurse being monitored. With greater saturation of Sevoflurane in patients' tissues, the longer the "off-gassing period" is extended which may increase exposure to trace amounts of PACU personnel.

There are two possible explanations for the finding that residual Sevoflurane levels were recorded in the PACU nurse's breathing space on the second day of sampling when no patients who had received Sevoflurane were in the PACU. One possibility is that the Sevoflurane was not completely vented out of the PACU leaving residual amounts. Another possibility is that there was an error in collection or analysis of the air sample. The early morning sample had a Sevoflurane level of .09 ppm. This could indicate that even with an extreme length of time (overnight) Sevoflurane may remain in the environment. This could also be due to an error in collection or analysis of the air sample.

These results indicate that although Sevoflurane is a fast "off-loading" volatile anesthetic, trace levels in PACU are below NIOSH (1977) standards. The question remains: Are PACU nurses who care for more than two patients concurrently exposed to Sevoflurane levels greater than 2.0 ppm? This study was conducted in a PACU of a medium size hospital with only two operating rooms using Sevoflurane. There may be different levels of Sevoflurane in PACUs where it is used to a greater extent such as in children's hospitals. In children's hospitals, the combination of liberal use of Sevoflurane and recovery rooms with large numbers of patients exhaling Sevoflurane may result in higher PACU nurse exposure to Sevoflurane gases.

Despite several studies which have found high levels of waste anesthetic gases in PACU, Sevoflurane levels found in a PACU in this study were below NIOSH (1977) standards. About 2-5% of Sevoflurane is metabolized. The combination of a low biotransformation, and low blood gas solubility makes Sevoflurane tend to "off-load" quickly which limits the exposure time of PACU nurses. Therefore, the patient and

PACU nurses' shared breathing spaces may remain at acceptable levels for Sevoflurane.

In this study of a PACU in a medium size hospital, the Sevoflurane levels did not exceed NIOSH standards for waste anesthetic gases.

Recommendations

Studies should be conducted in PACUs in hospitals where Sevoflurane is used and PACU nurses are exposed to maximal levels by caring for several patients concurrently who have received Sevoflurane anesthetics.

It would be interesting to know if nurse anesthetists' are at risk for breathing high levels of Sevoflurane when they administer the agent. Since the breathing space of CRNA's in the operating room is in close proximity to patients airways when they administer Sevoflurane, they may be being exposed to high levels of this agent.

In Roy's Adaptation Model the focal stimuli for PACU nurses is the anesthesia exhaled by patients which elicits an adaptive response. In this study, Sevoflurane was measured as the focal stimuli and found to be within NIOSH (1977) safety standards. However, adaptation is the pooled effect of focal, contextual, and residual stimuli. Adaptation promotes a person's goals of survival, reproduction, growth, and mastery. The focal stimuli measured here should not contribute to maladaptive responses, since they are below dangerous levels. Knowledge of a safe working environment contributes to residual stimuli which represents PACU caregivers attitudes towards trace anesthetic gases; belief that the working environment is not hazardous; and positive working experiences within the PACU environment. Findings in this study do not support the perception that anesthetic waste gases, cause a hazardous PACU environment.

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APPENDICIES

APPENDIX A

Theoretical Model

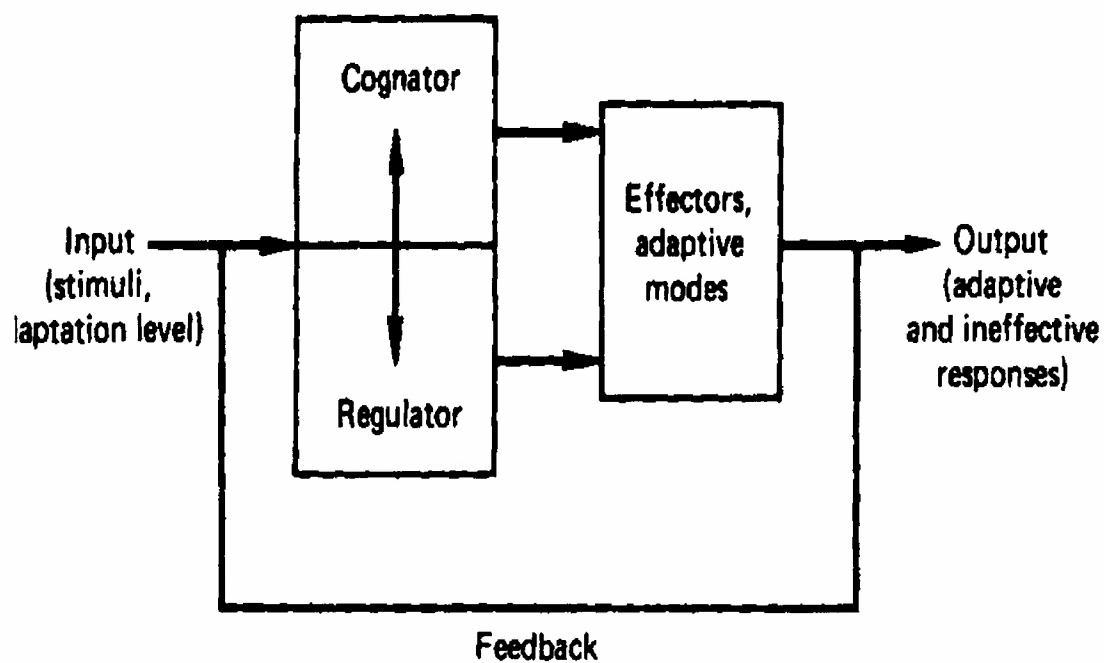


FIGURE 5.3 The Person as an Adaptive System.

Roy's Adaptation Model

APPENDIX B
Informed Consent

Informed Consent

Research Study

"HAZARDOUS POST ANESTHESIA CARE UNIT: REALITY OR MYTH?

A CASE STUDY"

My name is Major Marilee L. Edwards. I am a Nurse Anesthesia graduate student conducting research for my master's thesis. You are being asked to take part in a research study. Before you decide to be a part of this research study, you need to understand the risks and benefits so that you can make an informed decision. This is known as informed consent. This consent form provides information about the research study, which has been explained to you. Once you understand the study and the tests it requires, you will be asked to sign this form if you desire to participate in the study. Your decision participate is voluntary. This means that you are free to choose if you will take part in the study.

Purpose and Procedures

The Department of Nursing Anesthesia of the Uniformed Services University of the Health Sciences is carrying out this research study to find out whether sevoflurane levels in a Post Anesthesia Care Unit (PACU) meet the National Institute of Occupational Safety and Health standard of less than 2.0 parts per million (ppm). Two individuals will be randomly selected from a pool of PACU nurse volunteers to participate in this research study.

The procedure for this study includes the application of an air collection device (Ametek 2) to the individual's waist. The device is less than five pounds and will be worn for 90 minutes. Two 90 minute intervals will be performed during the day.

Benefits

The benefit of this study will provide data which evaluates the hazard of the PACU environment in relation to excess levels of anesthetic waste gases. The benefit is a safe working environment.

Time Commitment

The time commitment for this study will consist of two 90 minute sessions during the day shift in the Post Anesthetic Care Unit.

Risks, Inconveniences, Discomforts

There are no known potential risks of this study. If you have any known back problems please do not volunteer, you will be excluded from the study.

Cost of Participation

None to you.

Pregnancy

No pregnant women will be considered for this study.

Research Related Injury

This study should not entail any physical or mental risk beyond those described above. We do not expect complications to occur, but if, for any reason, you feel that continuing this study would constitute a hardship for you, we will end your participation in the study.

DoD will provide medical care at government facilities for any DoD eligible for injury or illness resulting from participation in this research. Such care may not be available to other research participants. Compensation may be available through judicial avenues to non-active duty research participants if they are injured through the negligence

(fault) of the Government.

If at any time you believe you have suffered an injury or illness as a result of participating in this research project you should contact the Office of Research Administration at the Uniformed Services University of the Health Sciences, Bethesda, MD 20814 at (301) 295-3303. This office can review the matter with you, can provide you information about your rights as a subject, and may be able to identify resources available to you. Information about judicial avenues of compensation is available from the University's General Counsel (301) 295-3028.

Confidentiality of Records

All information that you provide as a part of this study will be confidential and will be protected to the fullest extent of the law. Information that you provide and other records related to this study will be kept private, accessible only to those persons directly involved in conducting this study and members of the Uniformed Services University of the Health Science's Institutional Review Board, who provide oversight for human use protection. All questionnaires and forms will be kept in a restricted access, locked cabinet while not in use. However, please be advised that under UCMJ, a military member's confidentiality cannot be strictly guaranteed. To enhance the privacy of your responses you will not be identified on any of the data collection tools utilized. Any reports generated from this study will not divulge your name or identity.

Withdrawal

I understand that I may at any time during the course of this research study revoke my consent, and withdraw from the study without prejudice. I have been given an opportunity to ask questions concerning this research study, and any such questions have

been answered to my complete satisfaction. Call Marilee L. Edwards at 301-216-2832, If you have any concerns, questions, or Maura S. McAuliffe CRNA, Ph.D. at 301-295-6565, chair of my thesis committee. If you have any questions about your rights as a research subject, you should call the Director of Research Programs in the Office of Research at the Uniformed Services University of the Health Sciences at (301) 295-3303. This person is your representative and has no connection to the researchers conducting this study.

I do hereby volunteer to participate in a research study entitled: HAZARDOUS POST ANESTHESIA CARE UNIT: REALITY OF MYTH? A CASE STUDY. The implications of my voluntary participation: the nature, duration and purpose; the methods and means by which it is to be conducted; and the inconveniences and hazards to be expected have been thoroughly explained to me by

-----.

By signing this consent form you are agreeing that the study has been explained to you and that you understand this study. You are signing that you agree to take part in this study. You will be given a copy of this consent form.

I have been given the opportunity to ask questions concerning this study, and any such questions have been answered to my full and complete satisfaction.

Signature

Date

Signature (witness)

Date

I Certify that the research study has been explained to the above individual, by me, and that

the individual understands the nature and purpose, the possible risks and benefits associated with taking part in this research study. Any questions that have been raised have been answered.

Investigator

Date

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