THE QUALITY OF AIR IN THE POST-ANAESTHETIC CARE UNIT:

EFFECTS OF AN ANAESTHETIC GAS SCAVENGING SYSTEM

BY

MARY KATHLEEN KNIGHT KUBASIEWICZ

A thesis submitted to the University of Manitoba
in partial fulfillment of the requirements
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ABSTRACT

Exposure to waste anaesthetic gases is experienced by all personnel working in the operating room (O.R.) and post-anaesthetic care unit (P.A.C.U.). Over the last fifteen years, progress has been made in reducing this exposure in the O.R. through the introduction of local exhaust, or scavenging systems to remove waste gases. In the P.A.C.U., the only recommended method to decrease the levels of waste anaesthetic gases has been to increase ventilation, which is a difficult and expensive proposition.

At a community hospital, an anaesthetic gas scavenging system was developed and implemented to address occupational health concerns in the P.A.C.U. The system, which scavenges or removes waste anaesthetic gases as they are exhaled by the patient, was installed when it satisfied the regulatory government agency, and provided an acceptable solution to administration, medical staff and nursing personnel.

The purpose of this quantitative study was to measure the effects of the anaesthetic gas scavenging system on the quality of air in the P.A.C.U., as measured by the levels of nitrous oxide in the nurses' breathing zone and in the ambient air. Although the results of the analysis indicated that the gas scavenging system was effective in reducing the level of nitrous oxide, this difference was not statistically significant.

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DEDICATION

This thesis is dedicated:

To the nurses who work in the Post Anaesthesia Care Unit, and provide excellent care to patients during their emergence from anaesthesia: Stan, Lucy, Mickey, Leona, Marlene, Maria, Karen, Ember, Helga and Diane.

To Michal, whose presence in my life has made many things possible.

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Chapter 1

Introduction

Exposure to waste anaesthetic gases is experienced by all personnel working in the operating room (O.R.) and post-anaesthesia care unit (P.A.C.U.). Over the last fifteen years, progress has been made in reducing this exposure by the introduction of local exhaust (scavenging) systems in the O.R. to remove waste gases. However, in the P.A.C.U., the only recommended method to prevent the accumulation of waste gases (Brown et al, 1985; M.O.N.A., 1987) has been to improve the ventilation system. Such an undertaking could result in prohibitive costs, as well as lengthy disruptions in a critical care area.

The evidence that waste anaesthetic gases cause adverse health effects is not conclusive, and is the subject of controversy in the literature, between professional groups, and in staff-management relations (Brodsky, 1983a; M.O.N.A., 1987; Walts, 1983). A prudent course of action, such as the introduction of controls to reduce exposure, is recommended by the Canadian Centre for Occupational Health and Safety (Purdham, 1986) in view of the possible effects of high concentrations of waste anaesthetic gases upon reproductive outcome, kidney and liver function, and the central nervous system.

Background Information

Anaesthetic gases escape into the environment due to anaesthetic technique, leaks in the mechanical delivery system, lack of a well-functioning scavenging system, and from the patient's exhaled breath (Lecky, 1977; Sass-Kortsak et al., 1981). In the operating room, emphasis has been placed on identifying leaks in equipment, improving ventilation systems, installing scavenging systems, and monitoring anaesthetic technique and work practices (Brown et al., 1985; Lecky, 1977). In the Post-Anaesthetic Care Unit (P.A.C.U.), the patient is the source of waste anaesthetic gas, via expirations. The literature available on this problem in the P.A.C.U. advocates ensuring an adequate air exchange and frequent monitoring of the situation as the only solution (Brown et al., 1985; M.O.N.A., 1987).

At a community hospital in western Canada, an anaesthetic gas scavenging system (Appendix A) was developed and implemented in December, 1986, to address occupational health concerns in the P.A.C.U. (Kubasiewicz, 1987). Although the facility was only six years old, the ventilation system in the P.A.C.U. was inadequate, in that the waste anaesthetic gases could not be lowered to a level acceptable to the Department of Environment, Workplace Health and Safety (the regulatory government agency). The new system, which scavenges or removes waste anaesthetic gases as they are exhaled by the patient, was installed following assessment by the government agency, line and medical administration, and nursing staff. Preliminary testing of the system was done; however, a controlled evaluation was not conducted.

Purpose of the Study

The purpose of this quantitative study was to measure the effect of the anaesthetic gas scavenging system on the quality of air in the P.A.C.U., as measured by levels of nitrous oxide in the nurses' breathing zone and in the ambient air.

Hypotheses

The study evaluated the effect of a scavenging system on the quality of air in the Post-Anaesthetic Care Unit. The hypotheses for the study were:

Hypothesis I - An anaesthetic gas scavenging system in the P.A.C.U. will significantly improve the quality of air in the nurses' breathing zone.

Null Hypothesis I - An anaesthetic gas scavenging system in the P.A.C.U. will not significantly improve the quality of air in the nurses' breathing zone.

Hypothesis II - An anaesthetic gas scavenging system in the P.A.C.U. will significantly improve the quality of the ambient air.

Null Hypothesis II - An anaesthetic gas scavenging system in the P.A.C.U. will not significantly improve the quality of air in the ambient air.

Definition of Terms

For the purposes of this study, the following definitions and abbreviations are applied to the terms used in this thesis:

Toxicity (of a material) is its effects upon a living organism, or the inherent capacity of a substance to harm (Rudd, 1971; Sax, 1975). Toxic materials are toxic to all living things, although the susceptibility of different species and of individuals within each species varies. Toxic substances may cause disturbances of physiological substances resulting in repairable or irreparable damage to the organisms or individuals affected (Harrison, 1984).

Hazard (associated with a material) is a measure of the likelihood of damage to humans working with or exposed to the material (Sax, 1975). Hazard is the total risk taken when the material is used in practice.

N2O refers to nitrous oxide, an inhalational anaesthetic agent.

Occupational Health Hazard is the probability of exposure of a worker to a toxic substance in the course of their job-related duties.

O.R. is the Operating Room.

Post-Anaesthesia Care Unit (P.A.C.U.) refers to the nursing unit where patients who have had an anaesthetic receive specialized care during the immediate post-operative period. The P.A.C.U. is also referred to as a recovery room.

Dosimeter is a passive chemical device, which is used to provide a dose-related measure of an individual's exposure to a specific substance (in this thesis, nitrous oxide), during a specific period (Landauer, 1984).

Time Weighted Average (T.W.A.) is the person's exposure divided by the exposure time, and indicates the average concentration of the exposure (Landauer, 1984).

PPM-Hours is the parts per million hours, and is the measure of exposure. PPM-Hours is the product of the concentration of nitrous oxide in the P.A.C.U. environment and the time spent in that environment (Landauer, 1984).

Ambient Air refers to air in the atmosphere, i.e. in the P.A.C.U.

Nurse's Breathing Zone refers to the immediate vicinity of a nurse's mouth and nose, approximately a one foot radius.

Limitations of the Study

Types of ventilation systems, air exchange rates, and other environmental factors differ between recovery rooms, and therefore limit the generalizability of the findings to other settings. While the findings of the study are not generalizable to other settings, they are of import to the body of knowledge related to the control of possible occupational hazards in the P.A.C.U.

Conceptual Framework

The conceptual framework for this study is general systems theory. A system is defined as a set of components interacting with each other, with a boundary which filters the type and rate of inputs and outputs of the system (Berrien, 1968). An open system is one which is in constant interaction with the environment, and which continuously accepts and responds to inputs (Berrien, 1968; Chin, 1969).

A system is assumed to have a tendency to achieve equilibrium, or a balance among the various forces operating within and upon it (Chin, 1969). The system responds to stress, strains, or conflicts, and is in a constant process of adaptation. Another important component in systems theory is feedback, in which some portion of the system's output is returned to that system as input in order to modify subsequent outputs of the system (Pierce, 1972).

The field of occupational health is amenable to a systems analysis, in that such an approach can clearly identify the inputs of the system and provide a framework for controlling or monitoring the situation. Within this context, the individual is viewed as an open system, in constant interaction with the environment. Therefore, the well-being of nurses employed in the P.A.C.U. is affected by the environment in which they work. The P.A.C.U. nurse is the focus of the model, and waste anaesthetic gases are viewed as one of the inputs to the system. A model of a systems approach to the study topic is attached in Appendix B.

Summary

The effects of waste anaesthetic gases on personnel exposed in an occupational setting have not been conclusively proven. However, it is recommended (and required by governmental agencies) that levels of waste anaesthetic gases in the environment be minimized. This chapter has described the background and the plan for a study designed to explore the effects of an anaesthetic gas scavenging system on the quality of air in the P.A.C.U. A systems approach provided the basis for the conceptualization of the study, and a quantitative methodology provided the framework for the investigation.

Organization of the Thesis

This thesis is organized according to a standard format. Chapter one includes the background information, the purpose, and the hypotheses. Chapter two is a review of the pertinent literature. The methodology of the study is discussed in chapter three, and the findings of this investigation are presented in chapter four. Chapter five presents a summary of the findings and discusses the relevance of these findings.

Chapter 2

Review of the Literature

This chapter begins by discussing the concept of occupational health hazards in general, and then focuses on hazards specifically related to inhalational anaesthetics. The sources and effects of waste anaesthetic gases in the post-anaesthetic care unit are presented, the control and monitoring methods available are discussed, and the current state of guidelines and standards is described. The review of the literature concludes with a synopsis of the published critiques of the literature and a summary.

Occupational Health Hazards

Hazardous wastes are defined by Bird and Rapport (1986) as those that, because of their nature and quantity, are potentially harmful to human health and/or the environment, and require special disposal techniques. Hazardous wastes may exhibit any of the following characteristics: explosiveness; inflammability; oxidation; acute toxicity; corrosiveness; and, gas in a compressed state (Bird & Rapport, 1986).

Rudd (1971) and Sax (1975) differentiate between the concepts of hazard and toxicity. The toxicity of a material is its effects upon a living organism, or the inherent capacity of a substance to harm. Toxic materials are toxic to all living things, although the susceptibility of species and of individuals within each species varies. Toxic substances may cause disturbances of the physiological processes resulting in repairable or irreparable damage to the organism affected (Harrison, 1984). The hazard associated with a material is simply a measure of the likelihood of damage to humans working with or exposed to the material. Hazard is the total risk taken when the material is used in practice.

A degree of hazard, or risk, is inherent in the use of every toxic substance, and a decision must be made as to the acceptability of the risk. Factors to be considered include the speed of action of the substance, length of exposure to it, and the effects on the individual. Effects on the body could include irritation of the skin, mucous membranes or lung tissue; systemic effects, including damage to the nervous system, kidneys, liver, brain, or hemopoietic system; reproductive system effects; or carcinogenic effects (Harrison, 1984; Nader, 1974). Whether the risk of exposure to a substance is defined as reasonable is influenced by considerations of social benefit, availability of a substitute, and degree of exposure necessary (Chapman Walsh & Egdahl, 1980).

The occupational health literature recognizes that the hospital environment is fraught with hazards to the employee.

In this context, a hazard is defined as a "substance" which can harm health or endanger health (Kinnersley, 1979). Lewy (1981) divides occupational hazards in the hospital environment into four broad categories: occupational injuries and accidents; infections; toxicological hazards; and, stress. A similar classification system by Hopkins (1987) used the following categories: physical hazards, toxins, radiation, infectious agents, and burnout. In these contexts, waste anaesthetic gases are classified as potential toxological hazards. The recognition of hazards in the workplace is the necessary first step in the development of an effective occupational health program (Lewy, 1981).

The effect of waste anaesthetic gases on exposed personnel is a topic which has evoked debate in the literature (Walts, 1983; Brodsky, 1983a). Authors have summarized the research literature on the effects of waste anaesthetic gases and presented the results as an impetus to action (Purdham, 1986; Edling, 1980; Purdham, 1981; Rogers, 1986; Wilson & McEachern, 1985). The general consensus amongst these authors is that waste anaesthetic gases are suspected of causing a variety of untoward health effects in exposed personnel; however, causality has not been proven. Edling (1980), Mazze (1983), and Purdham (1981) stated that, despite methodological criticisms of the available research, the evidence suggests a higher risk for spontaneous abortion for women employed in the operating theatre. Less agreement is found regarding an increased risk for spontaneous abortion among women whose husbands have been chronically exposed, and regarding the incidence of birth defects, kidney disease, liver disease, and cancer (Edling, 1980; Purdham, 1981; Van Den Eeden & Wilkinson, 1985).

As advocated by the Canadian Centre for Occupational Health and Safety (Purdham, 1986), the prudent course of action is to introduce controls to reduce exposure. This recommendation was made in view of the possibilities that waste anaesthetic gases adversely affect reproductive outcome, and liver and kidney disease, and the lack of information on the effects on the central nervous system from long term exposure (Purdham, 1986). A multi-faceted approach is recommended to manage the exposure of personnel to waste anaesthetic gases. This includes the use of adequate ventilation, scavenging devices, careful administration of anaesthetic agents, and monitoring of both exposed personnel and the environment (Purdham, 1986; Brown et al., 1985; Fernsebner, 1987; Kubasiewicz, 1987; N.I.O.S.H., 1977; Omenn & Morris, 1984; Mazze, 1983; Purdham, 1981; Rogers, 1986; Ven Den Eeden & Wilkinson, 1985; Wilson & McEachern, 1985).

Inhalation Anaesthetics

Anaesthetic gases are therapeutic agents which are administered by anaesthesiologists to provide loss of sensation to enable surgical, dental, or obstetrical procedures to be performed. These agents have been used since the mid-1800's, when diethyl ether was used for general anaesthesia, nitrous oxide was used for dental surgery, and chloroform was used for childbirth (Purdham, 1986; Corbett, 1977; MONA, 1987). Few current pharmaceutical agents have been regularly used in medicine for a longer period than nitrous oxide. Omenn and Morris (1984) noted, "As has been stated so many times for Aspirin and other well-established agents, if nitrous oxide were proposed as a new drug today, it would probably not be approved for release" (p.130).

The most frequently used anaesthetic agents are nitrous oxide and halothane (fluothane). Of these two agents, halothane has a higher solubility in fat tissue. The consequence of this is that for a given duration of simultaneous exposure to both agents, tissue exposure to halothane is longer than to nitrous oxide, because halothane is retained longer in the body (Smith, 1978). Corbett (1972) reported the detection of traces of halothane in the end-expired breath of anaesthesiologists for seven to sixty-four hours following occupational exposure, compared with three to seven hours for detection of nitrous oxide. The elimination of halothane from the body following exposure is much slower than that of nitrous oxide.

Sources of Waste Anaesthetic Gases in the P.A.C.U.

The discussion in the literature of the sources of waste anaesthetic gases has concentrated on the operating room environment. In a statement of advice to the members of the Association of Anaesthetists of Great Britain and Ireland, Vickers (1975) outlined ten steps which should be taken to reduce atmospheric pollution to the lowest practicable levels. These measures, which focus on anaesthetic technique, preventative maintenance, ensuring adequate ventilation, and vigilant monitoring, are repeated by many authors: Ackerman (1985); Brown et al. (1985); Bruce (1973); Purdham (1986); Landauer (1984); Lecky (1977); and, Sass-Kortsak et al. (1981).

In the Post-Anaesthetic Care Unit (P.A.C.U.), the post-operative patient is the source of waste anaesthetic gas, via expired air. The largest percentage of anaesthetic gas is exhaled by the patient immediately following completion of administration, which occurs in the period of time spent in the P.A.C.U. As cited by Azar (1981), crowded and poorly ventilated recovery rooms have been found to be contaminated by levels of nitrous oxide and halothane.

The Canadian Centre for Occupational Health and Safety (Purdham, 1986) recommended improving general ventilation as the only effective way to deal with anaesthetic gases present from the exhalations of patients. In 1987, the Manitoba

Organization of Nurses' Associations (M.O.N.A.) indicated that the only solution for decreasing exposure is to provide fresh air exchanges to the area, as "all other acceptable methods for control of exposure such as personal protective devices and barriers between nurses and patients are impracticable and potentially dangerous to the patient" (p.12). However, ventilation alone proved to be insufficient in addressing occupational health concerns as documented by a regulatory agency, when unsafe levels of waste anaesthetic gases were found in a P.A.C.U. (Kubasiewicz, 1987).

The Effects of Waste Anaesthetic Gases

The first reports to indicate that people working in operating rooms could become ill as a consequence of exposure to anaesthetic gases, especially chloroform, came at the end of the 19th century (Edling, 1980). These included reports of symptoms including headaches, weakness, dizziness, and anorexia (Rogers, 1986). Purdham (1981), in a review of recent investigations aimed at identifying the health hazards faced by operating room personnel, emphasized that the investigations had not succeeded in definitely establishing a relationship between the effects observed and exposure to anaesthetic gases. This controversy and the limitations surrounding the literature on the effects of waste anaesthetic gases will be more completely discussed at the conclusion of this review: the remainder of this chapter will focus on presenting the findings in the literature.

Carcinogenicity

Several studies have attempted to explore the incidence of cancer in personnel exposed to waste anaesthetic gases. This research is logical, as certain inhalational anaesthetics have chemical structures roughly similar to known carcinogens, and their metabolic degradation pathways result in compounds that also may be suspected of being carcinogenic (Corbett, 1981).

An early survey by Corbett and others (1973b) examined the incidence of malignancy in 621 nurse-anaesthetists in Michigan. The study found that the study group experienced a higher incidence of malignancies during 1971 than did all the women of Connecticut during 1966 - 1969. These findings were interpreted to suggest that anaesthetia personnel may be at increased risk for the development of malignancies (Corbett et al., 1973b).

In a national study of occupational disease among operating room personnel, which was supported by the American Society of Anesthesiologists (A.S.A.), Cohen et al. (1974) suggested that the incidence of cancer in anesthesiologists was probably higher than that in pediatricians, although only in females. In his discussion of the findings of the A.S.A. study, Corbett (1977) stated that the frequency of cancer was 1.3 - 2 times greater among exposed women. The highest risk occurred among the women physician-anaesthetists, followed by nurse-anesthetists.

Spence et al. (1977) did a comparative analysis of data from three large retrospective surveys in the United States and the United Kingdom, and found that, in both countries, male anesthetists are not at higher risk with respect to cancer or leukemia. In a survey of anaesthetists and their families in the West Midlands of Britain, Tomlin (1979) observed cancer in both the adults and their children. However, Ferstandig (1978) showed that when all the available data were considered, there was no significant difference between the cancer rate experienced by the nurse anesthetists and the control group. All studies of the causes of death among anaesthetists have failed to show any unusual mortality rate for any form of cancer (Bruce et al., 1968; Bruce et al., 1974; Linde et al., 1981).

The two animal studies carried out by Corbett in 1976 (Halsey, 1981) and Eger et al. (1978) resulted in conflicting conclusions. Numerous methodological improvements in the study by Eger et al. (1978), which was based on Corbett's work, provided negative evidence for the carcinogenic potential of enflurane, halothane, methoxyflurane, and nitrous oxide. The lack of animal carcinogenicity has also been demonstrated in studies on mice inhaling halothane (Baden et al., 1979; Coate et al., 1979). As summarized by Ferstandig (1978), none of the animal studies in which current anaesthetics were used has produced evidence of carcinogenicity.

To summarize, there are many structural similarities between some known human carcinogens and several of the anaesthetic agents now in use (Corbett, 1981; Edling, 1980). However, as stated by Fink and Cullen (1976), no evidence has been found to indicate that long-continued trace exposure causes cancer.

Toxicity

Any chronic exposure of a biological system to a foreign chemical will produce changes in that system depending on the duration of exposure and the concentration achieved as a result of that exposure (Van Dyke, 1978). Several studies have attempted to create a toxic effect on laboratory animals, or have taken measures from personnel who have been chronically exposed to anaesthetic gases.

Kripke et al. (1976) studied testicular reaction by exposing rats to nitrous oxide for prolonged periods of time. There was a significant toxic effect, which was confined to the spermatogenic cells, with consequent reduction in mature spermatozoa. Spermatogenesis recovered after return to room air for more than three days (Kripke et al., 1976). Baden et al. (1982) exposed mice to high concentrations of enflurane, but could detect no effect on reproductive organs or spermatogenesis.

Nunn and O'Morain (1982) demonstrated that nitrous oxide decreases the motility of neutrophils, which is significant when contrasted with the effects of halothane, a more potent anaesthetic, which causes an increase in motility. Cleaton-Jones et al. (1977) exposed rats to nitrous oxide for periods ranging from 1 week to 6 months, and found no change in haemopoiesis, other than a transient polycythaemia.

Stevens et al. (1977) measured the toxic effects of subanaesthetic concentrations of nitrous oxide, enflurane, and fluroxene. Fluroxene produced the greater toxic effect, while nitrous oxide had little detrimental effect. A study by Lane et al. (1979) compared the effects of nitrous oxide and xenon on pregnant rats. Nitrous oxide caused a significantly higher incidence of resorptions, gross lesions and skeletal anomalies than in the xenon or control groups. The authors suggested that these results may be relevant when considering the use of nitrous oxide in the first trimester of pregnancy and in the consideration of occupational health hazards of O.R. personnel (Lane et al., 1979).

Several studies have been done which focus on the effects of nitrous oxide on hemopoiesis. In an editorial by Nunn and Chanarin (1978), attention was drawn to the fact that nitrous oxide reacts chemically with vitamin B12, and causes megloblastic anaemia. Amess (cited in Nunn & Chanarin, 1978) found that administration of nitrous oxide to patients for periods exceeding six hours produced mild to severe (at 24 hours) signs of megaloblastic depression of bone marrow. The effects are partially reversed by the administration of vitamin B12, and diminish on withdrawal of the nitrous oxide. A study by O'Sullivan and colleagues (1981) confirmed that prolonged exposure to nitrous oxide impairs bone marrow function temporarily, and that this effect may be prevented by the prior administration of folinic acid.

Sweeney et al. (1985) measured the exposure of 21 dentists to nitrous oxide in their actual practices by dosimetry, and performed a detailed medical history and physical examination. The examination included aspiration of sternal bone marrow. The study provided direct evidence that occupational exposure to nitrous oxide may cause depression of vitamin B12 function and that this results in measurable changes in bone marrow secondary to impaired synthesis of Deoxyriboneucleic Acid, or D.N.A. (Sweeney et al., 1985).

Activity of methionine synthetase was measured by liver biopsy, in seven patients receiving nitrous oxide, and in seven patients anaesthetized without nitrous oxide (Koblin et al. 1982). The authors found that inactivation of methionine synthetase (which may impair D.N.A. and protein synthesis) progressively increased as the product of the concentration of nitrous oxide and the exposure time increased. The suggestion was made that inactivation of methionine synthetase may be related to the increase of hepatic, renal, and neurologic disease seen in patients and medical personnel after prolonged exposure to anaesthetic and trace levels of nitrous oxide (Koblin et al., 1982).

Halsey (1981) reviewed the literature pertaining to the toxicity of inhalational anaesthetics. He concluded that further research will concentrate on the question of the toxic effects of the low level contaminant anaesthetic concentrations in operating rooms and the extension of teratogenicity testing to include fertility tests on males before mating (Halsey, 1981).

Nervous System Effects

Researchers have attempted to measure the effects of anaesthetic gases on the nervous system, by using such indicators as decision-making behaviours, perceptual, cognitive, and motor skills. Bruce, Bach and Arbit (1974) demonstrated a significant decrease in subject performance following exposure to nitrous oxide and halothane, as indicated by results in an audio-visual test, memory tests, and a visual tachistoscopic test. Subjects exposed to nitrous oxide alone showed a significant negative effect only on the digit-span test. In 1975, Bruce and Bach did a similar study, in which they exposed subjects to nitrous oxide and enflurane. Significant effects were found with the audio-visual and digit-span tests. A significant effect was also found on the digit-span test with subjects exposed only to nitrous oxide (Bruce & Bach, 1975). The authors concluded that these findings confirm that trace anaesthetic concentrations in amounts found in operating rooms not specially equipped for elimination of overflow anaesthetic gases may interfere with optimum performance on psychological tests measuring perceptual, cognitive, and motor skills.

Bentin, Collins and Adam (1978a) assessed the influence of subanaesthetic concentrations of enflurane on risk-taking tendency in human volunteers. They found that the subjects were more impulsive in their responses, willing to adopt risky strategies, and specifically, that they did not avoid the same risks which had been avoided under control conditions. In a second study, the authors found that exposure to subanaesthetic concentration of enflurane slowed the rate of learning, and increased the number of trials required to change previously developed decision strategies (Bentin et al., 1978b).

Korttila et al. (1978b) studied the effect of halothane and nitrous oxide on operating room and ward nurses' psychomotor and driving skills. The researchers compared the skills of operating room nurses 15 and 60 minutes after leaving the theatres with the skills of volunteer ward nurses 4.5 hours after administration of 3.5 minutes of general anaesthesia. Despite their higher age and greater amounts of halothane in their end-tidal air, the driving skills of the operating room nurses were similar to those of the ward nurses. The authors suggest that tolerance to anaesthetic gases develops after daily exposure to anaesthetic gases much as tolerance to the effects of alcohol develops among alcoholics (Korttila et al., 1978b).

A study by Cook and colleagues (1978) did not confirm the previous studies by Bruce and Bach (1978a, 1978b), although the work was patterned after that research. Cook's results suggested that mental function in operating room personnel is unaffected by ordinary trace levels of anaesthetics (Cook et al., 1978). Frankhuizen et al. (1978) attempted to duplicate the results with Bach's audio-visual test (Bruce et al, 1978a), but improved the study by making it a double-blind design. Exposure to 1600 p.p.m. of nitrous oxide and 16 p.p.m. of halothane did not have any adverse effects on performance in several cognitive tasks (Frankhuizen et al., 1978).

Gambill, McCallum, and Henrichs (1979) studied the performances on three psychomotor tasks of volunteers who were routinely and daily exposed to trace concentrations of anaesthetic gases in the course of their clinical practice. They did not detect any effect attributable to exposure to trace concentrations of anaesthetics. The authors concluded that laboratory studies may overestimate the degree of alteration of psychomotor skills associated with occupational exposure to anaesthetic gases (Gambill et al., 1979).

Venables et al. (1983) attempted to replicate Bruce and Bach's results (1978a, 1978b), using a similar audio-visual test. At a low concentration, nitrous oxide did not produce any statistically significant changes in psychomotor performance (Venables et al., 1983).

A survey questionnaire was mailed to 30,000 dentists (with additional copies included for their chairside assistants) requesting information regarding professional exposure to anaesthetics and health problems (Brodsky et al., 1981). A significant finding for both dentists and their assistants was an increased incidence of neurologic complaints, especially reports of numbness, tingling, and muscle weakness. Exposure to halothane in addition to nitrous oxide did not increase the incidence of complaints compared to those exposed to nitrous oxide alone. Brodsky et al. (1981) suggested that occupational exposure to nitrous oxide may be associated to neuropathy, similar to the severe polyneuropathy which results from nitrous oxide abuse.

In a systems review of the toxicity of nitrous oxide, Brodsky (1983b) defined the nitrous oxide neuropathy as a sensorimotor polyneuropathy, which is often combined with signs of spinal cord involvement. Initial symptoms are numbness, paresthesia, ataxia and clumsiness of the extremities. Continued exposure to nitrous oxide can lead to weakness, gait disturbances, impotence, and loss of sphincter control. Brodsky (1983b) uses the evidence that nitrous oxide interferes with vitamin B12 activity to support the belief that depression of vitamin B12 function is the etiology of nitrous oxide neuropathy, as the vitamin B12 - dependent enzyme methionine synthetase is essential for maintenance of D.N.A. and myelin biosynthesis in nervous tissue.

Smith and Shirley (1978) reviewed the effects of trace concentrations of anaesthetics on performance. They noted that results from three independent laboratories in three different countries failed to confirm the results of Bruce and Bach (1978a, 1978b), and concluded that it is reasonable to state that there is no convincing evidence that occupational exposure to anaesthetic agents has any effect on the psychomotor performance of healthy subjects. They did indicate that when using unscavenged anaesthetic circuits, the resulting exposure of anaesthetists to high concentrations of anaesthetic agents could conceivably cause impairment of performance, that chronic exposure differs from acute exposure, and that tolerance could develop (Smith & Shirley, 1978).

Reproductive Outcome

A variety of reports have been published which indicate that occupational exposure to waste anaesthetic gases can have a deleterious effect on reproductive outcome. In 1971, Cohen, Bellville and Brown surveyed two groups: operating room and general duty nurses; and, anaesthetists and other physicians. The investigators found a significantly higher spontaneous abortion rate in both operating room nurses and anaesthetists.

There also was a slightly higher miscarriage rate in the physician anaesthetist group compared to the operating room nurse group, which the authors attributed to the physician's exposure to the higher concentrations nearer the anaesthetic machine (Cohen et al., 1971).

Knill-Jones and his colleagues (1972) surveyed women anaesthetists in the United Kingdom, and found an increased ratio of spontaneous abortions to live births and an increased frequency of congenital abnormality in live-born children of women working as anaesthetists in the first six months of pregnancy, compared to anaesthetists not at work and non-anaesthetists. The women anaesthetists also had a higher incidence of infertility than the control group (Knill-Jones et al., 1972).

In response to the above studies, Rosenberg and Kirves (1973) surveyed Finnish women working as anaesthesia, scrub, casualty and intensive care nurses. The scrub nurses had the highest frequency of miscarriages, followed by the intensive care nurses, anaesthesia nurses, and casualty nurses. The authors attributed the increased rate of miscarriage to physical stress or excessive workloads, with the possibility of operating room pollution being an additive factor (Rosenberg & Kirves, 1973).

Corbett (1972; 1973a) found embryotoxicity in the rat, when nitrous oxide was chronically administered. He proposed that the pregnant women had a simple choice - to either stay out of the operating room during pregnancy, or to work only in operating rooms equipped with efficient gas-scavenging devices (Corbett, 1972).

A survey of 621 nurse-anaesthetists was performed to determine the incidence of birth defects. The data suggested that offspring of practicing female anaesthesia personnel are at increased risk of congenital abnormalities, in that a 16.4 % rate of anomalies was found in children whose mothers worked, while a rate of 5.7% occurred in children whose mothers did not work during the pregnancy (Corbett et al., 1974). Knill-Jones and his colleagues (1975) carried out a large survey of 7,949 male doctors. They found that maternal exposure was associated with a significantly greater frequency of spontaneous abortion (Knill-Jones et al., 1975).

Pharoah, Alberman, and Doyle (1977) surveyed 5,700 women doctors regarding the outcome of their pregnancies. Although there was no significant difference in the spontaneous abortion rate, conceptions which occurred when the mother was in an anaesthetic appointment resulted in smaller babies, higher still-birth rates, and more congenital abnormalities (Pharoah et al., 1977). A retrospective study by Rosenberg and Vanttinen (1978), showed that anaesthetic gas pollution may not be hazardous to the reproductive system. Although not statistically significant, the study detected nine musculoskeletal abnormalities among the anaesthetist group, but none among the pediatrician group.

Wharton et al. (1978) performed reproductive studies on mice, to determine the effects of subanaesthetic and anaesthetic concentrations of halothane. The lowest level at which adverse reproductive effects were found was approximately 40 times greater than the level of human occupational exposure in unscavenged operating rooms. The postnatal survival data indicated that prenatal exposure to halothane does not result in lethal developmental abnormalities (Wharton et al., 1978).

A study to determine the threshold concentration of nitrous oxide necessary to produce adverse responses in pregnant rats was done by Vieira et al. (1980). They stated that the data suggested that the critical nitrous oxide concentration that will cause fetal death and resorption in rats lies between 0.05% and 0.1%. The authors extrapolated from this that the arbitrary threshold limit value of 30 p.p.m. (i.e. 0.003%) may be well below the actual safety limits (Vieira et al., 1980).

Ericson and Kallen (1979, 1985) did two retrospective surveys of the outcome of delivery of women working in operating rooms during their pregnancy, using register data. In the two studies, no differences in the incidence of threatened abortions, in birth weight, in perinatal death rate, or in the incidence of congenital abnormalities were found (Ericson & Kallen, 1979, 1985). However, one of their studies (1979) could not examine the incidence of spontaneous abortion, as the data only referred to women who gave birth, and in the other (1985), data was available only on those hospitalized for spontaneous abortion. The authors state that the negative outcome of the study with regard to miscarriages may be attributed to the absence of registration of early miscarriages (Ericson & Kallen, 1985). Axelsson and Rylander (1982) designed a study to test the results obtained from a mailed questionnaire regarding pregnancy outcome for women exposed to anaesthetic gases during pregnancy. This was done by using a group of Swedish hospital employees, and validating the responses to the questionnnaire by comparing them to data from hospital records. The study indicated that all women suffering a miscarriage while working in an environment with exposure to anaesthetic gases reported the information accurately, while one third of all miscarriages occurring to women who were not exposed during pregnancy were not reported, demonstrating selective recall bias (Axelsson & Rylander, 1982). Hemminki, Kyyronen, and Lindbohm (1985) carried out a similar survey in Finland, using register data, except they sought out information on the first trimester of pregnancy from the head nurses of the hospitals where the subjects worked. The study detected no significant increase in the frequency of spontaneous abortions and malformations in the offspring of nurses exposed to anaesthetic gases, but as the odds ratio was above unity, a small effect from anaesthetic gases could not be ruled out (Hemminki et al., 1985).

In a study in Paris, interviews with women working in hospitals (excluding doctors) were conducted to determine in a more general manner the relationships between occupations, working conditions and the development and outcome of pregnancy (Saurel-Cubizolles et al., 1985). The results indicated that exposure to three specific working conditions (heavy cleaning, carrying heavy loads, long periods of standing) and their synergistic effect, was linked to higher frequencies of uterine contractions, high blood pressure, and preterm delivery (Saurel-Cubizolles et al., 1985). This study provided support for the suggestion by Rosenberg and Kirves (1973) that excessive workload may be a factor in reproductive outcome, not necessarily exposure to waste anaesthetic gases.

An investigation was done of adverse reproductive outcome in veterinary personnel who are exposed to waste anaesthetic gas at levels near the N.I.O.S.H. (1977) recommended standards (Johnson et al., 1987). The study found that occupational exposure to waste anaesthetic gases was not significantly associated with adverse reproductive outcomes, but the authors indicate that the numbers of controls and cases were too small to show statistical significance. However, there was a statistically significant increased risk of spontaneous abortion among wives of male veterinarians exposed to nitrous oxide (Johnson et al., 1987).

A study was done by Cohen et al. (1980) which studied the effects of long-term exposure to anaesthetic gases in 61,197 dentists and chairside assistants. An increased rate of spontaneous abortion was associated with either maternal or paternal exposure to trace anaesthetics in the dental operatory. While paternal exposure did not have a significant effect on the incidence of congenital abnormalities, direct light exposure of women was associated with an increase in the rate of anomalies (Cohen et al., 1980). Michenfelder (1980) points out the improvements in this study over previous ones, in that the control and exposed groups were essentially identical in terms of occupational profile except for the differences in anaesthetic exposures, and because many dentists use only nitrous oxide, the effects of this substance alone could be evaluated. According to Michenfelder (1980), this study demonstrated an apparent dose-response relationship for spontaneous abortion, as well as for kidney, liver and neurologic diseases, and cannot easily be refuted or ignored.

The epidemiological literature relating to anaesthetic exposure and reproductive outcome was reviewed by Tannenbaum and Goldberg (1985). They found major methodological flaws, including the following: 1) All studies used a retrospective cohort design, which is subject to biases in sample selection, inadequate response rates, attrition, and difficulties in standardizing outcomes. 2) Different populations were studied, such as anaesthetists, nurses, dentists, and veterinarians, and these occupations all have different levels of exposure to anaesthetic gases. 3) The study groups were identified through professional associations, and thereby excluded individuals who had left their work permanently - potentially a different population. 4) Comparison group selection was most commonly a separate population, such as general duty nurses (who might differ in aspects as working conditions, stress, etc. and thereby confound the results), or another group within the same population, as in the dental study, where age was found to be a confounding factor. 5) Generally, data collection was done by recall, although attempts were made by Ericson and Kallen (1979, 1985) to validate data with register information. 6) "Exposure" was not quantified. 7) Response rates were often low. 8) There were many confounding variables. The reviewers suggested that the consistency of the results may be explained in part by the consistency of the methodological problems (Tannenbaum & Goldberg, 1985).

Mortality

There have been several studies done of the mortality of anaesthesiologists, to assist in determining the occurrence of occupational disease within that group. In 1968, Bruce, Eide, Linde, and Eckenhoff verified and analyzed the deaths of members of the American Society of Anesthesiologists (A.S.A.) from 1947 to 1966, and compared the data with that released by Metropolitan Life Insurance Company. The authors found a high incidence of suicide, and a high death rate from malignancies of the lymphoid and reticuloendothelial tissues (Bruce et al., 1968). A similar survey was done of anaesthesiologist mortality for the years 1967 to 1971, using a similar methodology. The high suicide rate for this group was confirmed, but the earlier finding of a high incidence of lymphoid and reticuloendothelial tissue cancers was not replicated (Bruce et al., 1974). Cohen (1979) suggested that, although the incidence of cancer in both studies is the same as in the control groups, the indication that 80-90 per cent of all cancer is probably of environmental origin is of interest in view of the long term exposure of anaesthetiologists to waste gases in the operating room.

Lew (1979) studied the mortality experience among the American Society of Anesthesiologists (A.S.A.) from 1954 to 1976, making a special effort to trace deaths among all members who had stopped paying dues, when the death occurred within three years of the last payment of dues. This was done to control for the possibility that those who had stopped paying dues had done so on account of poor health. The investigation was designed to determine whether members of the A.S.A. who had been exposed to waste gases for prolonged periods experienced higher mortality from all causes, some forms of cancer, and some forms of hepatic and renal disease (Lew, 1979). The results of the survey indicated that the major problem among anaesthesiologists appears to be a high mortality rate from suicide.

Linde et al. (1981) conducted a review of causes of death among anaesthesiologists during the years 1930 to 1946. The study found that the causes of death were the same as among the control group. Although the incidence of suicides among the anaesthesiologists was not significant, the authors commented that during the Depression years, the overall rate of death by suicide among white males was high, which could have affected the results (Linde et al., 1981).

McNamee, Keen, and Corkill (1987) compared the rates of early retirement due to ill health among anaesthetists with those among other hospital doctors, to look for evidence of an occupational hazard in anaesthesia. They found that male consultant anaesthetists have statistically significant excesses of both ill-health retirements and normal, early (age 60-64) retirements, and that they have a higher rate of deaths while working than the other specialities. The authors offered two possible explanations: exposure to anaesthetic gases and stress (McNamee et al., 1987).

Health Hazards

Many articles in the literature have broadly addressed the issue of the health of personnel exposed to waste anaesthetic gases in the workplace. Linde and Bruce (1969) measured the concentrations of nitrous oxide or halothane in the air of operating rooms while the anaesthetics were being administered to assess the exposure of operating room personnel to anaesthetic vapours. They found that anaesthetists in the two hospitals studied inhaled modest amounts of halothane (10 p.p.m.) and nitrous oxide (130 p.p.m.) while working in operating rooms. Halothane was also found in the air expired by anaesthetists, and fluorine-containing substances (metabolic by-products) were found in their urine (Linde & Bruce, 1969).

In 1974, the report of an an hoc committee of the American Society of Anesthesiologists (A.S.A.) was published, which outlined the results of a national survey of occupational disease among operating room personnel. This study was a collaborative effort between the A.S.A. and N.I.O.S.H., and was based on 40,044 responses, an unprecedented statistical base in this field (Cohen et al., 1974). The questionnaire was mailed to the entire memberships of the American Society of Anesthesiologists, the American Association of Nurse Anesthetists, the Association of Operating Room Nurses, and the Association of Operating Room Technicians. The results indicated that an increased risk of spontaneous abortion existed among exposed females, that there was an increased incidence of congenital defects among children born of exposed personnel, and that there were unexpectedly high rates of cancer and diseases of the liver and kidney (Greene, 1974). The report clearly indicated that no data existed which demonstrated a causal relationship between the increased risk and trace concentrations of anaesthetic gases. Alternative hypotheses such as emotional stresses and strains, hours of work, or some other cause were discussed (Cohen et al., 1974; Greene, 1974).

However, the same ad hoc committee published a phamphlet under the auspices of the A.S.A. which offered a "how-to" approach to reduce exposure to waste anaesthetic gases (Lecky, no date). Moreover, the report was published with an accompanying editorial, which stated that "failure to install exhaust systems and failure to use them at all times represents in the light of present knowledge an unconscionable practice, a practice of exposing oneself as well as others to a demonstrable hazard" (Greene, 1974, p. 318). This report quickly elicited a response by Walts, Forsythe and Moore (1975), who objected to the editorial and identified three areas of concern with the report: the methodology used to collect the data; the selection of the level of significance, considering the potential impact of the false-positive conclusion in the areas of legal liability and recruitment into the specialty; and, the logic used to derive conclusions.

Spence et al. (1977) performed a comparative analysis of data from three large retrospective surveys in the United States and the United Kingdom, which investigated the effects of anaesthetic practice on the health of anaesthetists. The analysis suggests that the practice of anaesthesia is associated with an increased risk of congenital abnormalities for live-born children of both exposed men and women, and increased rates of hepatitis (Spence et al., 1977).

Vessey (1978) conducted a critical review of published epidemiological studies of the possible occupational hazards of anaesthesia. The methodology of the studies was discussed, including concerns with the population samples, response rates, the quality of the questionnaires, and the choice of end points. Vessey (1978) found reasonably convincing evidence of a moderate increase in the risk of spontaneous abortion among exposed females, although this is qualified by mentioning that even this result is attributable to reporting bias.

A study by Korttila et al. (1978a) measured the concentrations of nitrous oxide in the blood and end-tidal air of ten operating room nurses, using gas chromatography. It was determined that after cessation of exposure to nitrous oxide, there was a rapid decrease in the concentrations in blood and end-tidal air, but that small amounts of nitrous oxide remained in the body for at least three days after cessation of exposure (Korttila et al, 1978a).

Tomlin (1979) surveyed anaesthetists in the West Midlands (approximately 10% of anaesthetists in England and Wales) to determine their health problems. With the criterion that inclusion in the survey was based on referral to a consultant, one in ten of the subjects' children had a congenital or non-acquired anomaly. The anomalies were concentrated in the central nervous and musculo-skeletal systems, and girls were most severely affected. Unexpected infertility, cancer in both the adults and children, and the possibility of impaired intellectual development in the children were also raised. Tomlin (1979) obtained details of the ventilation in every area used to administer anaesthetics, and found inadequate ventilation and scavenging systems.

Vessey and Nunn (1980) reviewed investigations which focussed on the occupational hazards of anaesthesia, and determined that there was no consensus. However, they found it reasonably conclusive that there is an increased risk of abortion in theatre staff and that intermittent exposure to high concentrations of nitrous oxide can interfere with vitamin B12 metabolism. It was noted that to a large extent, the recommended levels are arbitrary and no "safe" level of exposure has yet been defined, although the authors recommended that steps should be taken to reduce contamination of the atmosphere in operating theatres as much as reasonably possible (Vessey & Nunn, 1980).

A survey of Belgian nurses and physicians was undertaken to evaluate whether there is a risk to the health of personnel working in the operating theatre (Lauwerys et al., 1981). No statistically significant differences were found between the exposed and control groups for miscarriages, congenital malformations, stillbirths, premature births, or for hepatic or renal disease. A higher frequency of headaches was found in anaesthetists and operating theatre nurses than in the control groups, which the investigators postulated could be related to the stress of working in the operating theatre and/or irregular hours of work (Lauwerys et al., 1981).

Nunn (1981) reviewed the state of knowledge relating to the consequences of exposure to trace levels of anaesthetic gases, and noted the following:

1. Anaesthetics reversibly inhibit cell multiplication, but only at high concentrations;

2. Nitrous oxide oxidizes vitamin B12 to an inactive form, which induces megaloblastic changes in bone marrow and may account for the leukopenia that follows prolonged exposure to nitrous oxide. This may also account for the neurological symptoms that may follow chronic exposure to levels higher than those occurring in the occupational setting;

3. Evidence exists that the abortion rate of female operating room personnel is about double the normal rate; and,

4. There are conflicting reports that children of exposed female staff may have a slightly higher rate of congenital anomalies.

In conclusion, Nunn (1981) noted that there was now sufficient evidence to recommend scavenging of anaesthetic gases wherever patients are being anaesthetized.

Buring et al. (1985) calculated relative risks in an attempt to evaluate the health experiences of operating room personnel, using previously published reports. This investigation was commissioned by the American Society of Anesthesiologists to evaluate the epidemiologic surveys that examined the putative health hazards attributed to exposure to waste anaesthetic gases (Mazze & Lecky, 1985). Relative risk was defined as the ratio of the disease rate among an exposed group compared with a control population. The authors found consistent evidence for increased incidence of spontaneous abortion among pregnant physicians and nurses who work in the operating room, and an increase in liver disease among both men and women (Buring et al., 1985). However, it was noted that most of the studies included relied on voluntary responses, so that recall bias could have been an explanation, and that working in an operating room was the inclusion criteria, not quantifiable exposure to waste anaesthetic gases. In a related editorial, Mazze and Lecky (1985) emphasize the limitations of the work, in particular the absence of verification of the medical outcomes reported in the studies used and the lack of any measurement of exposure to waste anaesthetic gases.

A study by Sonander, Stenqvist and Nilsson (1985) measured the exposure to nitrous oxide during different types of routine anaesthetic work in a Swedish hospital, and the efficiency of a scavenging system. The results indicated that anaesthetic work in operating theatres with good general air conditioning using waste gas scavenging system and tight equipment resulted in low exposure to nitrous oxide. No alarming levels of exposure were found even during shorter periods of work mainly with mask anaesthesia. However, the authors noted that a significant part of the period measured was spent in non-polluted environments during the preparation of the patient, transportation to and reporting in the recovery room (Sonander et al., 1985).

Several studies have attempted to measure the relationship between exposure to waste anaesthetic gases and the incidence of health problems in dentists and their spouses. Cohen et al. (1975) found a statistically significant increase in the incidence of spontaneous abortion in the spouses of exposed dentists, compared to the spouses of unexposed dentists, and a highly statistically significant increase in the incidence of liver disease in the exposed group (Cohen et al., 1975).

In a subsequent and larger survey, Cohen and others (1980) found that both paternal and maternal exposure resulted in statistically significant increases in spontaneous abortions. The investigators also found that rates of liver disease, kidney disease, and general neurologic disease were higher in the exposed groups. These results were magnified in the analysis of the female chairside assistants' questionnaires (Cohen et al., 1980). In a related study, Reitsma (1985) notes that dental offices often had recirculating ventilation systems, which contributed to high levels of waste anaesthetic gases. Cohen et al. (1979) indicated that the level of exposure to high concentrations of waste anaesthetics in the dental operatory was at least two to three times greater than that found in hospital operating rooms.

Control and Monitoring of Exposure

Many authors have dealt with the question of what controls should be in place for waste anaesthetic gases, what monitoring should be carried out, and how that monitoring should be done.

Brown, Wetterstroem, and Finch (1985) conducted a trace gas study to assess levels of anaesthetic gas in the O.R. environment. Although standard turbulent air flow and non-recirculating systems were present, areas with high gas concentration were identified, and significant exposure of personnel was documented. Anaesthetic techniques and work practices were found to be the major contributors to waste anaesthesia levels in the O.R. (Brown et al., 1985).

A study in Alberta by Sass-Kortsak, Wheeler, and Purdham (1981) assessed the exposure of operating room personnel to nitrous oxide, halothane and enflurane during the average work day. They found that a scavenging system was effective in significantly reducing contamination from anaesthetic gases in operating rooms, and that a good general ventilation system alone was not sufficient. It was also noted that where maintenance programs for the anaesthesia equipment were designed for the detection and elimination of leakage, contaminant levels were significantly lower than in those hospitals where the maintenance programs were concerned solely with proper equipment function as directly related to patient care (Sass-Kortsak et al., 1981).

Ackerman (1985) described a monitoring program using commercially-available dosimeters for nursing staff working in areas which use nitrous oxide. Over a one year period, he found that the mean individual exposure decreased from approximately 750 p.p.m. to 200 p.p.m., which was attributed to heightened awareness of the potential for nitrous oxide exposure and closer attention to leak-free delivery of anaesthetics (Ackerman, 1985).

Landauer, a company which markets passive chemical dosimeters, recommends a monitoring program which rapidly detects leaks in an anaesthetic system, and provides reliable personal monitoring. The combination of an infra-red analyzer, which gives an instantaneous readout of N2O concentrations and therefore is useful for detecting leaks, and the use of dosimeters, which give a dose-related measure of an individual's exposure, is suggested as the ideal monitoring system (Landauer, 1984).

Choi-Lao (1981) investigated concentrations of halothane anaesthetic vapours in the operating rooms of two hospitals in the Ottawa region. Although all samples showed traces of halothane, the amounts were within the recommended guidelines. It was noted that, to achieve the lowest possible levels of halothane and other anaesthetics in the ambient air, a leakproof anaesthetic system with effective scavenging and an efficient venting system were essential, as well as careful attention to anaesthetic practice and maintenance of equipment (Choi-Lao, 1981).

Fernsebner (1987) described a quality assurance program which used dosimeters to monitor levels of ambient nitrous oxide, to assure employees in perioperative areas that levels of anaesthetic gases were within recommended permissible levels. The program was a collaborative effort between the departments of nursing, anaesthesia, and environmental health and safety, who established 25 p.p.m. as their recommended permissible level. The study found that certain types of typical patient workloads (i.e. high patient turnover in one room, pediatric patients, mask anaesthesia) produced levels of ambient N20 higher than the recommended permissible levels (Fernesbner, 1987).

An article by Lecky (1977) discussed the mechanical aspects of anaesthetic pollution control, and the three major strategies for controlling anaesthetic contamination. The first and most significant step in reducing trace gas levels is the installation of an effective scavenging system. However, Lecky (1977) cautioned that, in order to prevent hazards to the patient, it is important to select a system which protects the breathing circuit from elevated positive and negative pressures. Secondly, Lecky recommended that an ongoing equipment-leak-prevention maintenance program be instituted as part of an anti-pollution program. This should include both manufacturer's servicing of anaesthetic machines on a regular basis and in-house monitoring to ensure that equipment leakage is detected. Thirdly, Lecky advocated that anaesthetic technique be altered to:

1. Avoid turning on the nitrous oxide flowmeter or vaporizer until the mask is fitted to the patient's face, or the patient is intubated and connected to the circuit;

2. Administer oxygen as long as possible at the end of a case, before extubation or removal of the mask, so that the scavenging system can remove the majority of the waste gases;

3. Fill vaporizers carefully to avoid spills; and,

4. Ensure a good fit of the mask.

The above recommendations were among those discussed by Vickers (1975) in a notice to members from the Council of the Association of Anaesthetists of Great Britain and Ireland, in order to move towards the goal of reducing atmospheric pollution as far as possible. However, Spence (1981) noted that by 1980 not more than one-third of all anaesthetizing locations in Britain were scavenged, partly due to maladministration in the Health Service and partly due to indifference to and confusion regarding the evidence of hazard.

An early study by Whitcher, Cohen and Trudell (1971) recommended that operating rooms be equipped with non-recirculating ventilation systems and that appropriately designed scavenging equipment be used in order to minimize the exposure of personnel. Whitcher and Piziali (1977) promoted air monitoring as an essential feature of any program to check occupational exposure to inhalation anaesthetics. Several ways to control occupational exposure to nitrous oxide in the dental operatory were suggested, including the use of a specially designed scavenging mask, venting the suction machine outside the building, and minimizing speech by the patient (Whitcher et al., 1977).

Whitcher and Siukola (1979) observed anaesthetists' work practices and suggested minor modifications, such as asking the circulating nurse to occlude the breathing circuit during essential disconnection, i.e. intubation and avoiding the use of anaesthetic gases prior to intubation, which are techniques that could reduce occupational anaesthetic exposure. They also reiterated that, with safe levels of anaesthetic exposure unestablished, the prudent course is to maintain the lowest reasonably achievable concentrations (Whitcher & Suikola, 1979).

An article by Robinson and others (1986) discussed the design and evaluation of a nitrous oxide scavenging system for use in non-traditional hospital settings, for example, a burn unit. A fan-powered scavenging system using a ceiling-mounted hood, under which nitrous oxide is administered, was found to maintain safe levels while requiring little patient cooperation and allowing complete access to the patient (Robinson et al., 1986).

A study was designed to evaluate the effectiveness of various methods of scavenging under operating room conditions (McIntyre et al., 1978). The results indicated that careful daily checks for and correction of high and low pressure leaks, combined with the use of a Foregger scavenging device and continuous wall vacuum, enabled mean values below the suggested levels (25 p.p.m. nitrous oxide, 5 p.p.m. halothane) to be achieved. The authors cautioned that no matter how much care is devoted to the design, selection, and installation of equipment to maintain a clean air environment, its value can be nullified if anaesthetists fail to use it intelligently or to maintain appropriate work practices (McIntyre et al., 1978).

An article by Eisenkraft (1984) advocated the use of certain control measures supported by an air monitoring program to achieve optimum reduction of air contamination. The monitoring is essential, and ensures the efficacy of control measures through the use of such devices as infrared analyzers and passive diffusion monitors, or dosimeters (Eisenkraft, 1984). In summary, it was noted that absence of evidence does not constitute evidence of absence, and that while the possibility of a hazard does exist, measures should be continued both to reduce exposure and to monitor the effects of these measures (Eisenkraft, 1984).

Piziali and others (1976) measured the distribution of waste anaesthetic gases in the operating room air to collect information to assist in reducing the exposure of personnel. The distribution of anaesthetic gases throughout the operating room was found to be a function of air-current mixing, diffusion, and buoyancy. Exhausting waste anaesthetic gases at floor level did not significantly reduce the exposure of personnel, but a non-recirculating air exchange system reduced waste gas concentrations.

A teaching guide for employees exposed to waste anaesthetic gases was developed by Letts and Wilkinson (1985), for use by occupational health nurses in educating operating room personnel about the potential risks associated with anaesthetic contaminated environment. The authors noted the need for accurate documentation in the employee's medical record of any complaint related to waste anaesthetic gas exposure and for preventive measures in the workplace (Letts & Wilkinson, 1985). Staff awareness of the potential problem was cited by Biddle (1984) as an important facet of any pollution control program, as it facilitates appropriate intervention.

In a similar vein, Lewy (1981) discussed the need to develop preventative strategies related to occupational health and safety programs in hospitals. Operating room personnel exposed to waste anaesthetic gases were singled out as requiring close monitoring due to exposure to these toxological hazards (Lewy, 1981).

Van Den Eeden and Wilkinson (1985) developed a health surveillance tool for use with employees exposed to waste anaesthetic gases. They discussed the responsibility of the occupational health service to institute employee biological monitoring or surveillance screening in light of a known or suspected hazard, and suggested its possible application as a risk management device (Van Den Eeden & Wilkinson, 1985).

Guidelines and Standards

The development of standards related to acceptable levels of waste anaesthetic gases in the ambient air has been a process full of controversy. In 1977, the U. S. National Institute for Occupational Safety and Health (N.I.O.S.H.) recommended a time-weighted average (T.W.A.) exposure guideline of 25 p.p.m. for nitrous oxide and 0.5 p.p.m. for each halogenated agent used in combination during the administration of anaesthetics, or 2 p.p.m. of a halogenated agent when used alone (Plant, 1978). These recommendations were the result of a collaborative effort in part by representatives of the American Society of Anesthesiologists, the Association of Operating Room Nurses, and N.I.O.S.H. Although these criteria have been widely applied in the workplace, they have not been formally adopted by the U.S. Department of Labor, Occupational Safety and Health

Administration (O.S.H.A.), which has the responsibility for the development, promulgation, and enforcement of standards (Geraci, 1977). However, Petty (1987) claimed that governmental intervention was probably unnecessary, since most (American) hospitals have instituted a waste-scavenging program.

In 1977, the American Hospital Association (A.H.A.) took the position of refusing to accept waste gases as a hazard. The association denied that waste gases are an institutionally controllable problem, since private-practicing anaesthetists administer the agents (Milliken, 1981).

Purdham (1981) noted that N.I.O.S.H. examined the information available, and attempted to set standards for exposure to halogenated anaesthetics and to nitrous oxide, acting mainly out of concern over the possibility of increased incidence of spontaneous abortion and birth defects. He remarked that the standards were intended to be used as achievable targets until such time as data became available which would allow quantification of the risk (Purdham, 1981).

In Ontario, the Ministry of Labour adopted a modification of the N.I.O.S.H. guidelines in 1981, i.e. 2 p.p.m. for halothane and enflurane, and 25 p.p.m. for nitrous oxide, whether alone or in combination with a halogenated agent (Ontario Ministry of Labour (1987).

The American Conference of Governmental Industrial Hygienists (A.C.G.I.H.) publishes recommendations to be used in the control of substances which are considered potential health hazards. In the most recent edition, notice of intended changes was given for three anaesthetic agents - enflurane (75 p.p.m.), halothane (50 p.p.m.), and nitrous oxide (50 p.p.m.) (ACGIH, 1987). In light of the existing polarization regarding the appropriate level for a standard (M.O.N.A., 1987; White et al., 1987), this recommendation will do little to allay the concerns of personnel exposed to waste anaesthetic gases.

Canadian standards have been published which deal with anaesthetic gas scavenging systems (Canadian Standards Association, 1982). These standards provide technical information which can be used as a guide to select a scavenging system from the several that are available.

Published Critiques

The possibility of adverse health effects resulting from exposure to waste anaesthetic gases in the workplace is a topic which evokes a varied response. Many efforts have been made to definitively critique existing literature and research. The conclusions of several of these critiques appear to be linked to the writer's professional interests.

Fink and Cullen (1976) concluded that chronic inhalation of trace amounts of anaesthetics is undesirable for a variety of reasons, and suggested that prophylactic scavenging should occur. However, they noted that it is premature to conclude that long-term exposure to trace levels of anaesthetic gases causes abortions, congenital malformations, or cancer, as the evidence is inconclusive (Fink & Cullen, 1976).

A critical review of the disease potential of waste anaesthetic gases as evidenced in the published literature was conducted by Ferstandig (1978), in light of the increasing concern regarding potential harmful effects. He found that there were no statistically sound studies which prove that trace concentrations of anaesthetic gases exert harmful effects. In particular, it was noted that all epidemiological studies to date on the effects on reproduction have serious flaws, and that none contains clear evidence of a cause and effect relationship between exposure and reproductive disease (Ferstandig, 1978).

An article by Light (1979) described the health hazards to which personnel working in the operating theatre are exposed, and discussed methods to control the pollution of the environment, such as scavenging and careful techniques used to handle and deliver anaesthetic agents. She concluded that although there was no conclusive proof, the present state of thinking was that there was an increased risk of spontaneous abortion with anaesthetic practice.

Edling (1980) reviewed the literature on the different health effects of long-term exposure to anaesthetic gases, and critiqued articles under the headings of teratogenicity and mutagenicity, carcinogenicity, and effects on other organs. He deduced that even if there are methodological weaknesses, many studies indicate a higher risk for spontaneous abortion among women exposed to anaesthetic gases. Less agreement was found in the information on the increased risk for spontaneous abortion or congenital anomalies among wives of exposed males, and to the reports of increased incidence of cancer, or kidney or liver disease (Edling, 1980).

In a series of articles which discussed how hospital employees can be endangered by the substances used in diagnosis and treatment, Mattia (1983) stated that the contaminating effects of inhalation anaesthetic gases upon operating room environments have been known ever since these substances were introduced. In reviewing the literature, Mattia (1983) noted that the overall data seem to indicate that occupational exposure to trace anaesthetic gases is associated with significant health problems, including increased rate of spontaneous abortion, stillbirths, congenital defects, cancer, hepatic and renal disease, and interference with vitamin B12 metabolism.

Mazze (1983) discussed the evidence presented by the epidemiological surveys, as the case against anaesthetic agents rests almost entirely upon these surveys. The methodological weaknesses of the studies were discussed, as were alternate possible explanations of the adverse health outcomes reported, such as the exposure to both biological and chemical, non-anaesthetic, toxic agents present in operating rooms (e.g. hepatitis virus, methymethacrylate monomer, and ionizing radiation). Mazze also detailed the results of an evaluation of the epidemiological surveys conducted by Epistat Associates, an independent, expert epidemiological-biostatistical consulting group engaged by the American Society of Anesthesiologists. The conclusions of the Epistat group were that:

1. Adverse reproductive outcomes for women directly exposed to anaesthetic gases during pregnancy are the only health effects for which there is reasonably consistent evidence;

2. Re-analysis of existing data sets would add little to present knowledge of the possible adverse effects of exposure to trace anaesthetic agents;

3. The epidemiological data available are insufficient for developing standards or setting exposure limits; and,

4. Further epidemiological investigations should take the form of prospective cohert studies, with careful documentation of the type, amount, and duration of exposure.

The direction offered by Mazze (1983) was that when waste anaesthetic gas concentrations can be lowered without compromising the quality of patient care and without incurring excessive costs, efforts should be made to scavenge.

In 1983, two articles appeared in the Association of Operating Room Nurses (A.O.R.N.) Journal which debated whether waste anaesthetic gases in the workplace constitute a health hazard. In the first article, Walts (1983) discussed the concerns with the methodology used in the epidemiological surveys, and the findings of the Epistat group. He concluded that until a study such as that recommended by the Epistat group is conducted, exposure to trace levels of anaesthetic gases will not have been proven to be harmful. However, Walts noted that due to the increased miscarriage rate, any operating room nurse should consider the total working environment as having an unhealthy effect on child-bearing (Walts, 1983).

In the rebuttal, Brodsky (1983) stated that trace levels of anaesthetic gases, particularly nitrous oxide, may impose a significant health hazard among exposed personnel. Although Brodsky recognized the weaknesses of the epidemiological studies, he took the view that one cannot ignore the fact that nearly all these studies concluded that occupational exposure to anaesthetic gases is a health hazard. It is also noted that a survey of dentists and chairside assistants (Cohen et al., 1980) showed an increase in both reproductive and general health risks associated with long-term exposure to waste anaesthetic gases. Brodsky (1983) also questioned the arguments for a study of the type recommended by the Epistat group. He argued that such a study would be prohibitively expensive, difficult to manage in terms of the number of subjects, and complicated in terms of measuring anaesthetic exposure. Brodsky questioned whether it would be feasible to find a suitable control group, i.e. subjects working under similar conditions to an operating room but unexposed to anaesthetic gases. The conclusion drawn was that even without direct proof, levels of waste gases should be reduced to their lowest possible concentrations by careful use of efficient control measures (Brodsky, 1983).

In a discussion of occupational health hazards in the recovery room, Stringer (1984) noted concerns related to levels of waste anaesthetic gases. Precautions recommended until the extent of the problem have been delineated included: having a minimum of twenty air exchanges per hour; using a non-recirculating ventilation system; reporting symptoms of gas exposure; not exposing oneself directly to the patient's mouth; regular monitoring; and, supporting efforts to change legislation concerning permissible levels of anaesthetic gases (Stringer, 1984).

Four recent articles in popular nursing journals have increased staff nurses' awareness of the effects of waste anaesthetic gases. Wilson & McEachern (1985) stated that all operating room personnel are exposed to increased health hazards associated with the operating room environment, including pollution from waste anaesthetic gases. Although recognizing the criticisms of the epidemiological literature, the authors indicated that a causal relationship between waste anaesthetic gases and hazards to humans has been established by the results of those studies (Wilson & McEachern, 1985). In one article in a series about hidden hazards on the job, Zelanko Eskesen (1986) discussed the dangerous levels of anaesthetic gases to which nurses may be exposed in operating rooms, in labour and delivery, or in a dental office. Rogers (1986) conducted a critique of literature and discussed control and monitoring measures to reduce exposure. She stated that exposure to waste anaesthetic gases represents a serious hazard to employees and possibly their families, although a causal effect has not been firmly established (Rogers, 1986). In an article by Hopkins (1987), anaesthetic gases were referred to as "toxins" which are not always removed from the environment by the scavenging system.

The Canadian Centre for Occupational Health and Safety published a document, purported to be a straightforward summary of the findings (Purdham, 1986). The report discussed the limitations of the epidemiological investigations, including biases which could arise from inadequate response rates, different response rates between control and exposed groups, difficulties in obtaining comparison groups, and lack of data which quantifies exposure levels. These epidemiological studies form the tenuous evidence that anaesthetic agents can cause adverse effects upon pregnancy outcome. The author noted that the results do not directly implicate anaesthetic gases, and that all the studies lacked quantitative data on exposure to these agents, thereby not demonstrating a cause-effect relationship or eliminating the effects of confounding variables (Purdham, 1986). The review also concluded that there was evidence of liver and kidney damage from exposure to anaesthetic agents, but only at concentrations much higher than that experienced in the occupational setting. The summary of the findings stated that "in view of the possibilities that anaesthetic agents adversely affect reproductive outcome, and liver and kidney at high concentrations, ... the prudent course of action is to introduce controls to reduce exposure" (Purdham, 1986, p.12).

An earlier critique by Purdham (1981) discussed the failure of researchers to rule out or control extraneous variables such as exposure to a variety of radiations, x-rays, ultraviolet and radiofrequency, freon propellants, methylmethacrylate, stress, infectious agents, and scrubbing agents (e.g. hexachlorophene). As part of a panel discussion on the occupational hazards of anaesthesia, a presentation was made on the environmental hazards associated with trace levels of anaesthetic gases (Pope et al., 1985). Dr. Halsey summarized the debate as follows: "Some feel that not enough is being done about the problem while others maintain either that there is no problem and that much research and finance has been misdirected, or that scavenging devices introduce an unacceptable hazard to the patient. In general, many feel that this is a well-worn subject about which there is considerable indifference and confusion amongst general operating room staff" (Pope et al., 1985, p.143).

Summary

The evidence regarding the occupational hazards of trace levels of anaesthetic gases is inconclusive. The epidemiological studies are flawed by methodological weaknesses which cast doubt on their findings. These weaknesses include small sample sizes, inequivalent comparison groups, lack of quantifiable data regarding the level of exposure to waste anaesthetic gases, absence of verification of medical histories, leading or suggestive questionnaires, and the possibility of recall bias affecting results. Conversely, most of these studies have found that exposure to low concentrations of anaesthetic gases may adversely affect reproductive outcome, including increasing the incidence of spontaneous abortion. Other studies have indicated that nitrous oxide can interfere with vitamin B12 metabolism.

In conclusion, the jury is still out on the question of whether exposure to low concentrations of anaesthetic gases constitutes an occupational health hazard. Undoubtedly, more research will be conducted; hopefully this will clarify the relationship. The question which remains to be addressed is what to do in the interim. There is a consensus in the literature that scavenging of waste anaesthetic gases should occur wherever anaesthetics are administered. This concept could logically be extended to post-anaesthesia care units, which have been found to be crowded, poorly ventilated, and contaminated by levels of nitrous oxide and halothane.

The difficult aspect of scavenging anaesthetic gases is coming to an agreement regarding the "safe" levels of these agents to be adhered to in the occupational setting. Negotiations need to occur between parties with vested interests, including occupational health and safety regulatory agencies, health funding agencies, hospital administrators, anaesthesiologists, operating room nurses, post-anaesthesia nurses, and dentists and their assistants, to determine the standard which will be used. Although this process would not be a simple one, it is essential to harmonious relations in the workplace, as much of the controversy surrounding the effects of waste anaesthetic gases has occurred when regulatory agencies have attempted to enforce standards which have not been accepted by some groups, but have been strongly endorsed by others.

Chapter 3

Methodology

The methodology of the study is discussed under the following headings: design, population, setting, instruments, ethical considerations, and data collection.

Design

This study measured the difference in the quality of air in the P.A.C.U. when a scavenging system was used to remove waste anaesthetic gases, which are exhaled by patients in the immediate postoperative period. The P.A.C.U., which is structurally identical on each side of the room (see Appendix C), was divided into side A and side B. Two nurses were randomly assigned to work on each side of the room. Patients who recovered on side A were connected to the scavenging system, which was the experimental intervention, or X. Patients on side B were not connected to the system, and were the comparison group. P.A.C.U. nursing care was provided as usual to all patients, according to individual needs.

The nurses wore dosimeters (Appendix D) to assess the effect of the scavenging system on the quality of air in their breathing zone, by continuously measuring levels of nitrous oxide. In addition, dosimeters were placed at strategic locations in the P.A.C.U., to measure levels of nitrous oxide in the ambient air (Appendix C).

The first ten patients of each day (fifty patients per week) were the source of the waste anaesthetic gases. The study ran for two weeks, for a total of one hundred patients. The experimental and comparison groups each consisted of fifty patients. At the end of the first week, the sides of the room were switched, i.e. side B then received patients who would be connected to the scavenging system rather than side A, and the study was repeated.

The quantitative methodology chosen for this research problem was the Posttest-Only Control Group Design (Campbell & Stanley, 1966). The form of the methodology is as follows:

R X O

R O

In this notation, X represents the exposure of a group to an experimental variable, the effects of which are to be measured; O refers to the process of measurement, and R represents random assignment to separate treatment groups (Campbell & Stanley, 1966).

Skodol Wilson (1985) calls this the simplest experimental design, in which the investigator assigns subjects to an experimental group and control group, but collects data only at the end of the treatment or exposure to the independent variable. The soundness of the design relies on being able to assume that the groups are comparable (Skodol Wilson, 1985).

Christiansen (1985) categorized this design, which he called a Between Subjects After-Only research design, as a true experimental design. Equivalence between the two groups is obtained through the use of randomization, which is sufficient within the limits of confidence stated by the tests of significance (Campbell & Stanley, 1966). This design was used because of its fit with the field of study, in that a pretest was not appropriate, and there was an experimental intervention to test.

Population

Since this study focused on the quality of air, no sample was identified. Discussion in this section of the thesis will concentrate on the dependent variable and the independent variables. The dependent variable of this study, or the variable that measures the influence of the independent variable (Christiansen, 1985), is the quality of air in the P.A.C.U. This was measured by the level of nitrous oxide, in both the ambient air and the nurses' breathing zone.

The independent variable, or the variable controlled by the experimenter, was manipulated using the presence versus absence technique to achieve variation (Christiansen, 1985). In this study the independent variable was the presence or absence of the anaesthetic gas scavenging system.

In addition, it was necessary to hold constant the effect of two variables, the patient groups and the nurses, each of which had several aspects. Randomization was used for assignment to the control and experimental groups, which mediated the effects of these potentially confounding factors (Skodol Wilson, 1985).

The first extraneous variable to be controlled was the patient group. The factors considered in connection with this variable were physical status or characteristics, surgical procedure performed, types of anaesthetic agents received and anaesthetic techniques used. The second extraneous variable was the nurses in the P.A.C.U. In this case, the aspects considered included relevant physical characteristics, idiosyncracies when providing patient care (e.g. closeness to patient's expired breath), and attitude towards waste anaesthetic gases.

Random selection ensured that each patient having surgery during the study's time frame had an equal chance of being selected to participate in the study (Shelley, 1984). The scheduling of patients in the Operating Room was not controlled by the study, and changes in a patient's place on the slate occurred due to many factors. Similarly, the assignment of nurses to work during the study period was not controlled by the investigator. These factors were assumed to be random influences.

Random assignment was then used to divide the patients who provide the source of waste anaesthetic gas (e.g. ten patients per day) into the experimental and control groups. This method of randomization controlled for extraneous variables, and was the best way of creating equivalent groups (Campbell & Stanley, 1966; Christiansen, 1985). A toss of a coin determined the assignment of the first patient each day into a group; heads, the patient went to the experimental group, tails, to the control group. Assignment to the groups alternated from this point onward.

A similar method was used to randomly assign nurses to work on either the experimental or control side of the P.A.C.U. A toss of a coin determined which group the first nurse would be assigned to, and assignment of the nursing staff alternated from there.

It was also important to control the environment to limit the confounding effect of waste anaesthetic gases "contaminating" the ambient air. As the number of patients cared for in the P.A.C.U. increases throughout the day, the level of anaesthetic gases in the ambient air could also vary, creating an uncontrolled extraneous variable. Therefore, the study was limited to the first ten patients arriving in the P.A.C.U. each day. Another reason to limit the level of waste anaesthetic gases in the ambient air was to minimize the exposure of staff.

Setting

The sample was selected from patients who had a general anaesthetic at the hospital during the study period. The

Post-Anaesthetic Care Unit (P.A.C.U.), or recovery room, was the setting for the study. The study took place in the regular work environment, with staff who are familiar with the use of the system.

The P.A.C.U. has a design similar to recovery rooms elsewhere in Canada (Appendix C). However, differences in types of ventilation systems, air exchange rates, and other environmental factors which differ between recovery rooms limit the generalizability of the findings.

Instrument

One instrument was used in the investigation - a passive chemical dosimeter, which measures nitrous oxide. Nitrous oxide is a rapid-acting inhalation agent used during general anaesthetics to reduce dosage of the more potent agents, e.g. the halogenated agents, by being used in conjunction with them (Fraulini, 1987). Although many drugs are used at the same time to anaesthetize patients, for ease of monitoring, the nitrous oxide component of anesthetic gas mixtures is generally accepted as an indicator of the level of gas (Sass-Kortsak et al., 1981); that is, if the levels of nitrous oxide are below 25 p.p.m T.W.A. (parts per million, time-weighted average), it is assumed that the levels of other materials are acceptable (Joint Council on Hospital Accreditation, 1985). The reason for this is that nitrous oxide is by far the most common anaesthetic gas and that the control limit is the least favourable in relation to commonly used concentrations (Sonander et al., 1985).

Other instruments which could be used to measure the levels of anaesthetic gas, such as infrared analyzers or nitrous oxide trace monitors, were not used as they do not provide a reliable measure of the workers' actual exposure. These devices are more suited for detecting and locating leaks in anaesthetic systems, as they give an instantaneous readout of nitrous oxide concentrations in a room (Landauer, 1984). However, such readings cannot easily be translated to the time-weighted measures which correlate to the recommended exposure levels. Another drawback to the use of these expensive devices is that the personnel who calibrate and read the analyzers must have special training.

Nitrous oxide dosimeters are small, easy to use, and have been used periodically in the P.A.C.U. over the past eighteen months (Appendix D). These instruments give a dose-related measure of an individual's exposure during the monitored period. In this context, exposure equals the product of the concentration of gas in the air and the duration of exposure to the gas. A badge-type (dosimeter) monitoring system complies with the standards of the American accreditation body, the Joint Council on Hospital Accreditation or J.C.H.A., (1985), is inexpensive, and requires little technical expertise to be correctly used.

Note: Throughout this study, reference will be made to

American standards, as currently there are no national standards in Canada. Provincial Workplace, Health and Safety Departments refer to the National Institute for Occupational Safety and Health (N.I.O.S.H.) standards (1977), although they have not been formally recognized by all provinces.

The nitrous oxide dosimeters which were used in the study were purchased from R. S. Landauer, Jr. & Co. (Illinois). The company indicated that the reliability of the instrument at 100 p.p.m. hours is plus or minus 6% in a controlled laboratory environment, or 9% in a field setting (R.S. Landauer, personal communication, May 10, 1988). Interrater reliability was not an issue in the study, as the analysis of the dosimeters was done by an independent laboratory, using computerized equipment.

Ethical Considerations

The investigator received approval for the study from two sources, The University of Manitoba School of Nursing Ethics Committee and The Board of Directors of the hospital. Patient consent was not obtained, as use of the scavenging system is routinely dependent on several patient-related factors, and whether or not the system is used does not affect the patient's care. Factors considered by a P.A.C.U. nurse in determining whether to connect the scavenging system include the type of anaesthetic, the surgical procedure, method of oxygen therapy, presence of equipment such as a respirator, whether the patient

is agitated or restless, and the patient's overall condition.

The investigator informed nurses as to the purpose and methodology of the study, and of the fact that they could withdraw at any time from the study without concern of consequence from such withdrawal. The nurses were also informed verbally and in writing that confidentiality would be maintained, and that access to identifiable data would be limited to the investigator, the thesis committee members, and the statistician. A sample of the consent form used to document each nurse's consent is reproduced in Appendix E.

A copy of the results of the study was sent to the facility.

Data Collection Techniques

The study measured the effects of a scavenging system on the quality of air in the P.A.C.U. The data was collected through the use of nitrous oxide dosimeters, which were worn by nurses working during the study period, and were placed at strategic locations in the P.A.C.U. (Appendix C). The dosimeters were analyzed by the manufacturer, who provided computer-generated reports (Appendix G). From these reports, the following information, located in the four columns under "Exposure", was used:

1. Guide T.W.A. - The generally accepted standard for personnel exposure, as measured in time weighted average.

2. Hours Uncapped - The amount of time the dosimeter was uncapped, or exposed to the environment. This exposure time was monitored and reported by the investigator.

3. P.P.M.-Hours - Parts per million hours, or the measure of the actual exposure to nitrous oxide, as analyzed by the laboratory. P.P.M.-Hours is the product of concentration of nitrous oxide in the P.A.C.U. environment and the time spent in that environment.

4. T.W.A. - Time weighted average is the exposure divided by the exposure time, and indicates the average concentration of the exposure.

Data Analysis Techniques

Data analysis concentrated on descriptive and statistical comparison of the experimental and control groups. The goal of the analysis was to determine the effect of an anaesthetic gas scavenging system on the quality of air in the P.A.C.U. A comparison of the patients in each group was done with respect to operation performed, anaesthetic technique, and other information to validate the representativeness of the groups.

The primary functions of the analysis were to compare the two patient groups and to evaluate the data received from the dosimeters. This was achieved by using the Wilcoxon Rank Sum test, which is the nonparametric test for comparing two independent groups (Schlotzhauer & Littell, 1987).

Chapter 4

Presentation of the Findings

In this chapter, the results of the study are presented. The data obtained from the patient groups are examined to ensure the groups were equivalent, and the nurse and cubicle dosimeter readings are analyzed to determine whether the presence of the anaesthetic gas scavenging system affected the levels of anaesthetic gases in the P.A.C.U. The final section of the chapter presents serendipitous and subjective findings related to the presence of the anaesthetic gas scavenging system in the P.A.C.U.

Comparison of Patient Groups

The control (without scavenging system) and experimental (with scavenging system) patient groups were compared using statistical techniques to ensure their similarity. These tests were done to check that randomization had indeed equated the groups, and that extraneous variables, known or unknown, would not systematically bias the study (Christiansen, 1985). Note: For the purposes of the study, week 1 refers to days 1 - 5, and week 2 refers to days 6 - 10.

Using S.A.S, a computerized statistical analysis program (Schlotzhauer & Littell, 1987), descriptive analysis was done of the patient group data sets, which are summarized in Tables

1 to 6. This analysis included sorting the data, and comparing the groups according to scavenging system (use or not), day of the study, patient age, length of anaesthesia, and length of time spent in the P.A.C.U. The analysis found that there was no significant difference between the groups according to age, length of anaesthesia, time in P.A.C.U., side of the P.A.C.U., or week. Accordingly, the groups were considered to be equivalent.

Figure 1 presents a summary of the means of three variables on which the patient groups were compared.

FIGURE 1

Patient Groups - Comparison of Means

	WITH SCAVENGING SYSTEM	WITHOUT SCAVENGING SYSTEM	
AGE	33.9	34.8	yrs.
LENGTH OF ANAESTHESIA	47.26	52.94	min.
P.A.C.U. TIME	59.08	61.76	min.

Nurse Dosimeter Data

A computerized statistical program was used to analyze the data obtained from the dosimeters worn by nurses providing care to patients who had the scavenging system attached, and to those who did not.

The nurse dosimeter data was sorted according to week (1 or 2) and by side (either side A or B; refer to Appendix C). The data was then compared by P.P.M. (parts per million, or level of nitrous oxide exposure), T.W.A. (time-weighted average, or the average concentration of exposure), and hours not capped (amount of time the dosimeter was used, which was monitored by the investigator). The data is attached in Table 7.

Further analysis was done using the Wilcoxon Rank Sum test, which is the nonparametric analogue to the two-sample t-test, and the Kruskal-Wallis test, which is the nonparametric equivalent to the one-way analysis of variance (Schlotzhauer & Littell, 1987).

The results of the analysis indicated that the presence or absence of the scavenging system did not affect the nurses' exposure to nitrous oxide. However, examination of the raw data revealed an unexpected result: two of the dosimeters used during the first week did not register any exposure to nitrous oxide (refer to Table 7, Total P.P.M. column).

Figure 2 displays the means of the nurses' dosimetry results. Although the two week average exposure for nurses working with the scavenger system is somewhat less than that for nurses working without the system, the difference is not statistically significant.

FIGURE 2

Nurse Dosimeter Data - Comparison of Means

	WITH SCAVENGER	WITHOUT SCAVENGER	
WEEK 1	24	64.5	PPM N2O
WEEK 2	78	63.5	PPM N2O
WEEK 1 & 2 (AVG)	51	64	PPM N2O

Attempts were then made to increase the precision of the analysis, and to adjust for any effect related to the side of the P.A.C.U. or the week the data was collected, although it was expected that the design of the study had controlled these variables. As anticipated, no effect was identified.

Cubicle Dosimeter Data

Dosimeters were used to measure the levels of nitrous oxide in the ambient air in each cubicle in the P.A.C.U. The results are attached in Table 8, which also includes other pertinent data such as the frequency of cubicle use, P.A.C.U. time by cubicle, and the length of anaesthesia.

Within the cubicle dosimeter data, there were four dosimeter readings of zero p.p.m., which indicated the dosimeter was not exposed to nitrous oxide. These results were similar to ones obtained with the nurse dosimeters, and were not anticipated.

The cubicle dosimeter data was analyzed using the computerized statistical program (Schlotzhauer & Littell, 1987). The data were sorted according to side and week, and then the results were compared using exposure (hours not capped), frequency of cubicle use, length of anaesthesia, P.A.C.U. time, P.P.M. (parts per million), and T.W.A. (time weighted average) as variables. The data was also analyzed using the nonparametric Wilcoxon Rank Sum test.

The results of the analysis indicated that presence or absence of the scavenging system did not affect the level of nitrous oxide in the ambient air. However, calculations of the estimated difference indicated that there was evidence the system was working, i.e. reducing the level of nitrous oxide, but that this was not at a statistically significant level.

Related Findings

When the study took place, the anaesthetic gas scavenging system had been operational for one and a half years. During the course of the study, it became apparent that there were serendipitous benefits related to the use of the anaesthetic gas scavenging system.

One advantage to using the scavenging system is the protection it affords nursing personnel from infectious materials. The oxygen face tent used in the system (refer to Appendix A) acts as a barrier when patients cough, something patients often do quite productively after a general anaesthetic. Nurses who worked on the side of the P.A.C.U. where the system was not being used indicated that they missed the protection the system afforded, and that they were more comfortable staying closer to the patients when they worked with the system.

Another finding related to the presence of the anaesthetic gas scavenging system was a sense of pride in the institution. The nurses were pleased that the administration had attempted to find a solution to the high levels of anaesthetic gases in the post-anaesthetic care unit, and they perceived that the hospital had been successful in improving the work environment.

The personnel working in the post-anaesthetic care unit also indicated that, during the study, they noticed a difference in the amount of anaesthetic gases they were exposed to when working on the side of the P.A.C.U. without the system. Two staff members indicated they had had headaches by the end of the day, and several stated that they were tired from "breathing the gases all day".

It is recognized that the above comments could be explained as either subject bias or a Hawthorne effect (Christiansen, 1985); however, they are presented here to provide context to the study.

Chapter 5

Summary, Recommendations and Conclusion

In this final chapter of the thesis, the findings of this investigation are summarized and presented in relation to the information documented in the review of the literature. The interpretation of the study includes the implications of the findings for further investigation and conclusion.

Summary of the Study

The purpose of this study was to measure the effect of an anaesthetic gas scavenging system on the quality of air in the Post-Anaesthesia Care Unit. A critique of the methodology selected to achieve this purpose appeared in Chapter 4.

The study was designed to provide a controlled evaluation of an anaesthetic gas scavenging system which was designed and implemented to address specific occupational health concerns in the P.A.C.U., and to satisify the regulatory agency. General systems theory provided the conceptual framework for the investigation, which recognizes inputs to the system, i.e. waste anaesthetic gases, and the interaction within the system, between such components as personnel, ventilation, and the gases.

The P.A.C.U., structurally identical on each side of the room, was divided into side A and side B. Two nurses were randomly assigned to work on each side of the room. During the first five days of data collection, patients recovered on side A had the scavenging system attached (the experimental intervention), while patients recovered on side B were not connected to the system. The first ten patients of each day (five patients per side daily, fifty patients per week) were the source of the waste anaesthetic gases. At the end of the first week (five days of data collection), the sides of the room were switched, that is, side B patients now were connected to the scavenging system, not those on side A, and the study was repeated. This was done to control for any environmental factors which had not been anticipated.

Nitrous oxide dosimeters, which continuously measure levels of nitrous oxide, were used to assess the effect of the scavenging system on the quality of air in the nurses' breathing zone. As there were several part-time nurses employed in the P.A.C.U., and only four nurses work each day, nurses were randomly assigned each day to a numbered dosimeter. The dosimeters were numbered and assigned to a specific side, and separate dosimeters were used for each week of the study. Dosimeters were also placed in each patient cubicle in the P.A.C.U. to determine the levels of nitrous oxide in the ambient air.

Discussion of the Findings

The results of this investigation did not provide sufficient evidence to justify the rejection of the null hypotheses, and therefore did not support the scientific hypotheses. The hypotheses for the study were:

Hypothesis I - An anaesthetic gas scavenging system in the P.A.C.U. will significantly improve the quality of air in the nurses' breathing zone.

Null Hypothesis I - An anaesthetic gas scavenging system in the P.A.C.U. will not significantly improve the quality of air in the nurses' breathing zone.

Hypothesis II - An anesthetic gas scavenging system in the P.A.C.U. will significantly improve the quality of the ambient air.

Null Hypothesis II - An anaesthetic gas scavenging system in the P.A.C.U. will not significantly improve the quality of air in the ambient air.

The analysis of the dosimeter data did not provide evidence to reject either null hypothesis. Previous communication with the company indicated that reliability of the dosimeter at 100 ppm is plus or minus 9% in a field setting, although when reviewing the very diverse data obtained in the study, that reliability is questioned.

Nurse Dosimeter Data

DOSI #	SCAVENGER	WEEK	SIDE	HRS NC	PPM	TWA
1	w/o	1	A	22.1	129	6
2	w/o	1	A	18.3	0	0
6	w	1	B	23.8	48	2
7	w	1	B	22.4	0	0

This excerpt from Table 7 demonstrates a difficulty with this data set - dosimeters 2 and 7 did not register any nitrous oxide during the hours not capped, 18.3 and 22.4 hours respectively. During week one, forty-eight out of fifty patients had received nitrous oxide during their anaesthesia, so the results showing no exposure to nitrous oxide are questionable.

Cubicle Dosimeter Data

DOSI #	SCAV	WEEK	SIDE	CUB	HRS NC	FREQ	LOA	PACU	PPM	TWA
3	w/o	1	A	6	26.5	13	712	851	42	2
5	w/o	1	A	4	25.5	2	91	138	0	0
8	w	1	B	1	28.8	11	477	606	43	2
9	w	1	B	2	27.3	12	624	786	0	0
13	w/o	2	B	1	26.9	13	667	803	19	1
15	w/o	2	B	3	22.3	3	119	205	0	0
18	w	2	A	6	26.6	16	729	984	0	0
19	w	2	A	5	23.8	8	404	405	32	1

LEGEND:
DOSI # - Dosimeter number
SCAV. - Presence or absence of scavenging system
WEEK - Week 1 or 2 of data collection
SIDE - Side of the PACU where dosimeter was located
CUB - Number of cubicle to which dosimeter was assigned
HOURS NC - Hours the dosimeter was not capped, or exposed
FREQ - Number of times a cubicle was used
TOTAL LOA - Cumulative length of anaesthesia in minutes for patients in cubicle specific to each dosimeter
TOTAL PACU - Cumulative length of time in PACU per dosimeter
PPM - Parts per million exposure according to dosimeter number
TWA - Time weighted average according to dosimeter number

This data also illustrates a problem with the results - it is difficult to accept that a nitrous oxide dosimeter could fail to register any ambient air exposure during a two week period when ninety-five out of one hundred patients had received nitrous oxide during their anaesthesia. Another concern is that the distribution of negative findings in the results is haphazard; it appears in different cubicles between the two weeks, and is not related to the frequency of cubicle use, length of anaesthesia, or time spent in the P.A.C.U.

These dosimeter results, for both nurse-related and cubicle-related data, are evidence that the investigation was confounded by the instrument.

Estimation calculations indicated that there was evidence that the system was working, but not at a level that was statistically significant. This suggests that the investigation be repeated, increasing the statistical power of the experiment.

The possibility of a confounding effect from the air currents in the room cannot be ruled out. Although the ventilation system is identical within the P.A.C.U., there are two large doors between the P.A.C.U. and O.R. close to side A (refer to Appendix C). The movement of these doors could disrupt air currents within the P.A.C.U., especially given the positive pressure ventilation which exists in the O.R. and not in the P.A.C.U.

effect was considered. However, given the random assignment of nurses to dosimeters and the fact that each "nurse" dosimeter was a composite of five different nurses' exposures to nitrous oxide, any such effect would have been mitigated.

Another possible explanation is that the levels of waste anaesthetic gases in the P.A.C.U. were so low that the dosimeters were unable to accurately detect exposure. When the P.A.C.U. was surveyed by Workplace Safety and Health in October 1986, levels of nitrous oxide were as high as 175 p.p.m. in the nurse's breathing zone with only three patients in the area. This placed the air in the P.A.C.U. within the reliability of the instrument, which is plus or minus 9% at 100 p.p.m. in a field setting.

Periodic monitoring has indicated that the levels of waste anaesthetic gas in the P.A.C.U. have decreased significantly since the 1986 survey. In June 1988, a survey of the P.A.C.U. was conducted by an independent industrial hygienist using an infra-red analyzer. At that time, two months prior to the study, the average concentration of nitrous oxide in the nurses' breathing zone was 6 p.p.m. over a 105 minute sample duration. The report, received during data collection, indicated that "Concentrations were reduced by 70 to 80 percent after the face tent scavenging system was in place" (Personal communication, July 21, 1988).

This survey provides evidence that the activities which took place between October 1986 and June 1988 had been successful in decreasing the level of waste anaesthetic gases in the environment. During that time, slight improvements were made in the ventilation system in P.A.C.U., the scavenging system was installed, and a memorandum was sent to remind all anaesthetists of ways their technique could reduce waste gas pollution. The memo suggested the "elimination of the majority of nitrous oxide and inhalation agents before extubation", which would decrease the amount of anaesthetic gases exhaled by the patient in the P.A.C.U. (Personal communication, June 9, 1987).

Although all three factors (improving ventilation, installing the scavenging system, and the memo) contributed to improving the quality of air in the P.A.C.U., the general consensus in the facility was that the scavenging system has had the greatest effect. This appears to be supported by the unsolicited comment by the industrial hygienist that the scavenging system reduced concentrations by 70 to 80 percent.

Another possible explanation relates to recent changes in anaesthetic technique. It is now common for patients to receive high levels of narcotics, which reduces the use of inhalational anaesthetics. The availability of short-acting narcotics, which are used in conjunction with local anaesthetics, has made this technique feasible, even for short-stay patients (Personal communication, December 7, 1988). This change in anaesthetic practice would also decrease the amount of anaesthetic gas exhaled by patients into the P.A.C.U.

Critique of the Methodology

Instrument credentialing refers to the process and procedures used to demonstrate that an instrument is good for use under certain conditions and with subjects who have certain characteristics (Shelley, 1984). The study would have been enhanced, and the outcomes affected, by field-testing or credentialing the instrument prior to data collection. The dosimeter results (Tables 7 and 8) show only three instances of p.p.m. at levels where the instrument would be functioning within its stated range of reliability. Pre-testing the instrument in the research setting would have increased the prospect of identifying difficulties with the instrument's sensitivity.

The study was designed so that the study was limited to the first ten patients of each day (Appendix F). This was done to limit the possibility of waste anaesthetic gases dispersing throughout the ambient air, and "contaminating" cubicle dosimeter readings. During data collection it was clear that the patient flow through the P.A.C.U. varied greatly between days, taking from between three and seven hours to obtain the quota of ten patients who had received general anaesthesia.

It is also possible that the levels of nitrous oxide observed during the study represented an average concentration: higher than that which would have occurred if the scavenging system had been used on both sides, but lower than if the system had not been used. There were two ways to control for this influence. The first option would be to repeat the experiment with a physical separation between the two sides, but this would be both prohibitively expensive and disruptive to patient care. Alternatively, concentrations could be measured with the system in use for all patients on both sides over a number of days, and compared with readings taken over an equal number of days without the system being in use on either side. This possibility had been considered and rejected during the design phase of the study, due to ethical considerations related to the total removal of the system for the study, with the resulting exposure of the staff to the waste anaesthetic gases.

Recommendations for Further Research

Although this investigation did not provide statistically significant evidence that the scavenging system in the P.A.C.U. had an effect on the quality of air, recommendations for further research in this field are offered because methodological factors could have prevented such an effect from being demonstrated. These recommendations are:

1. Increase the statistical power of the design to ensure that any effect would be illustrated. This could be done by

extending the study over a longer period of time.

2. Conduct a pilot study to measure the reliability of the dosimeters and to measure the effect of the scavenging system. This would be done in a controlled laboratory-type setting, with a device emitting pre-measured amounts of nitrous oxide comparable to that which a patient would exhale. The effect related to presence or absence of the scavenging system would be measured by dosimetry. The reliability of the dosimeters would be measured by comparing the results obtained without the system to the amount of nitrous oxide released into the controlled environment.

3. Repeat the study having the scavenging system either connected to all patients, or not connected to all patients. The purpose of this would be to physically separate the experimental intervention and control groups, so that any effect would be more pronounced.

4. In a more general sense, the changes in anaesthetic technique suggest an ongoing need to carefully evaluate each post anaesthesia care unit to determine the extent to which the quality of air is affected by the presence of waste anaesthetic gases prior to beginning any activity to decrease levels of gases. The changes in anaesthetic technique include improvements related to preventing the release of waste gases

into the environment, as well as the increasing emphasis on narcotic techniques and local anaesthesia.

5. Further research is also required with respect to the presence of occupational hazards in both the operating room and post anaesthesia care unit, to assess whether waste anaesthetic gases, stress, irregularities in workload, or other factors constitute health hazards.

Conclusion

The results of this study demonstrate that it is feasible to keep levels of waste anaesthetic gases in the P.A.C.U., as measured by the presence of nitrous oxide, well within the suggested guideline of 25 p.p.m. (N.I.O.S.H., 1977). Depending on the facility, three factors can be manipulated to minimize the presence of anaesthetic gases in the Post Anaesthesia Care Unit: 1. the ventilation system, which regulates the speed at which the gases are dispersed through the environment; 2. anaesthetic technique, which determines the amount of gases exhaled into the environment; and, 3. the presence of an anaesthetic gas scavenging system, which removes the gases as they are exhaled by the patient and prevents them from being dispersed into the ambient air. The environment in the P.A.C.U. can be controlled in a cost-efficient manner, so that the presence of waste anaesthetic gases is minimized.

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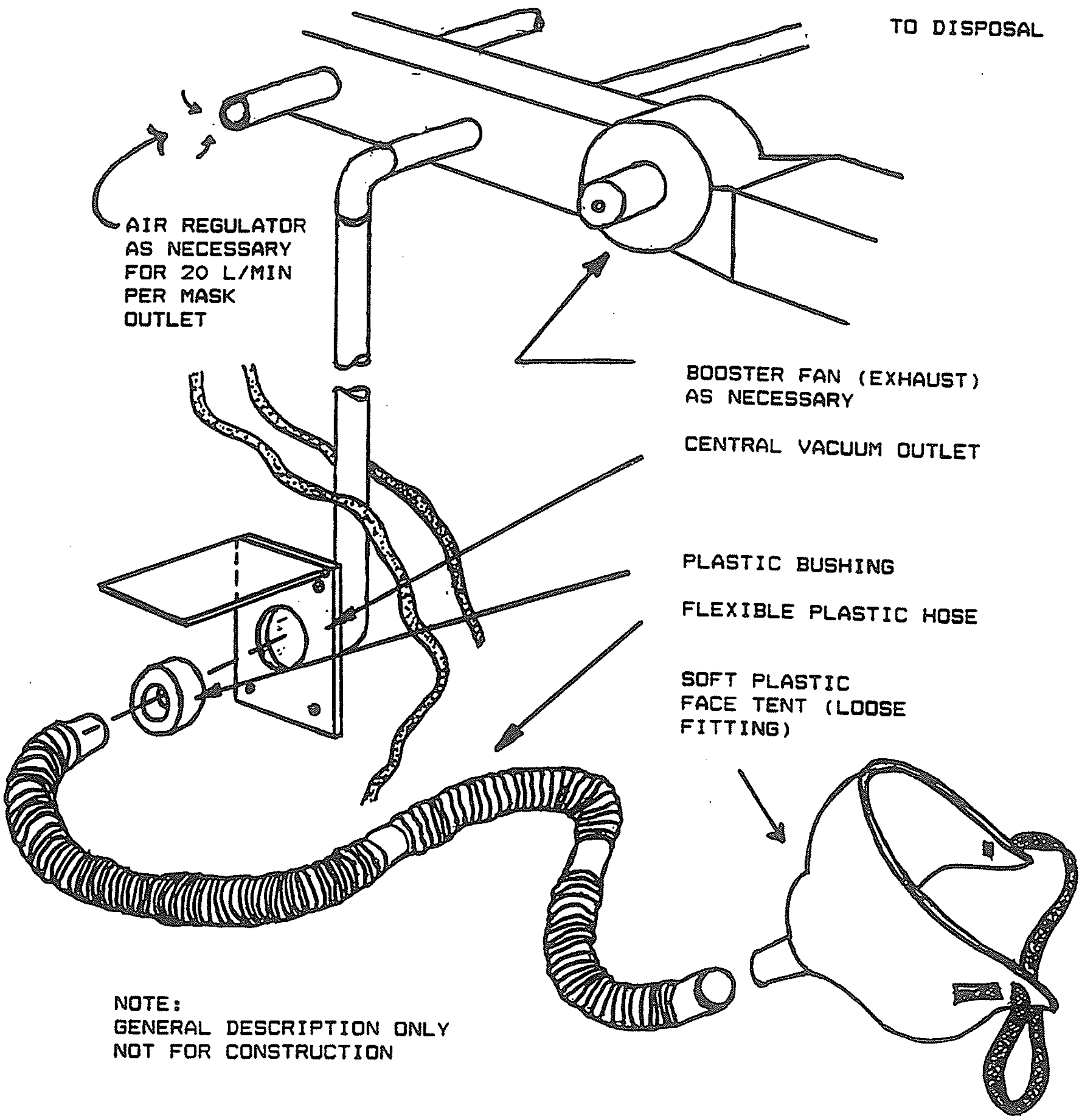
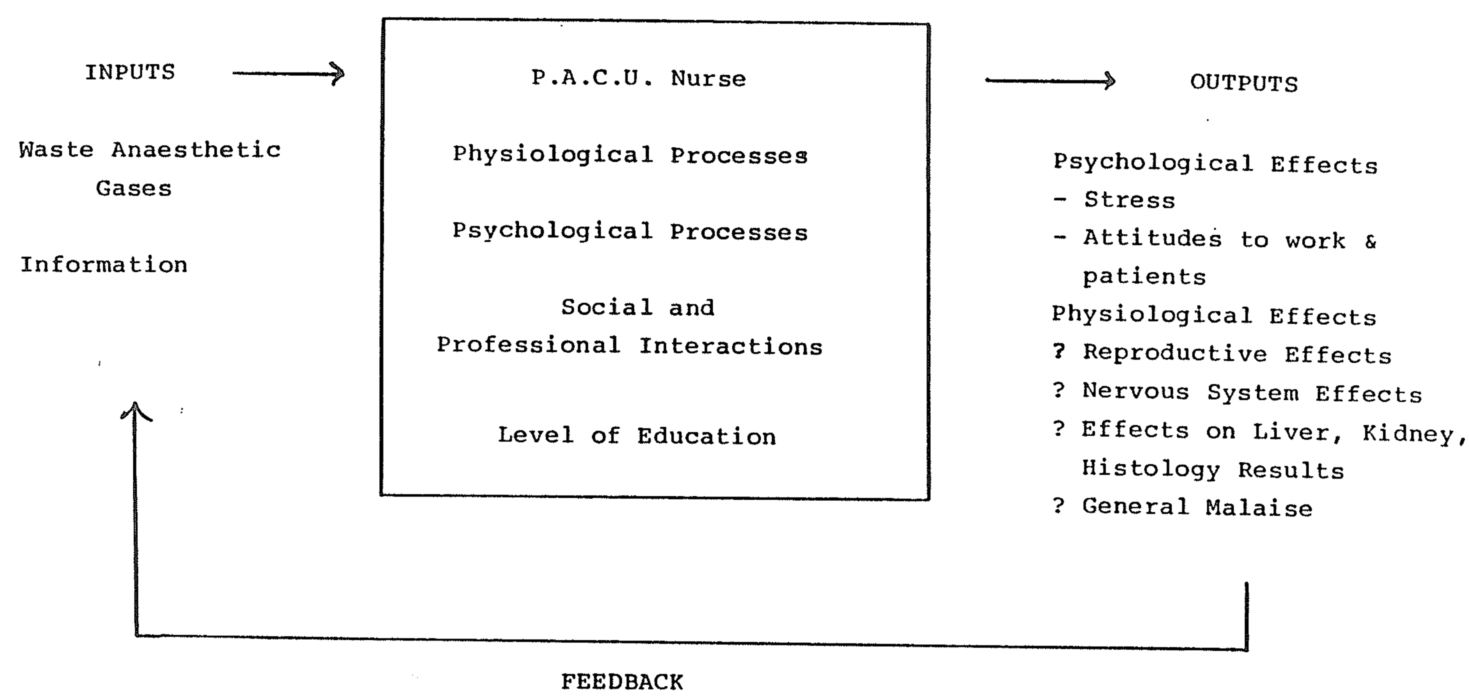
APPENDIX A

ANAESTHETIC GAS SCAVENGING SYSTEM



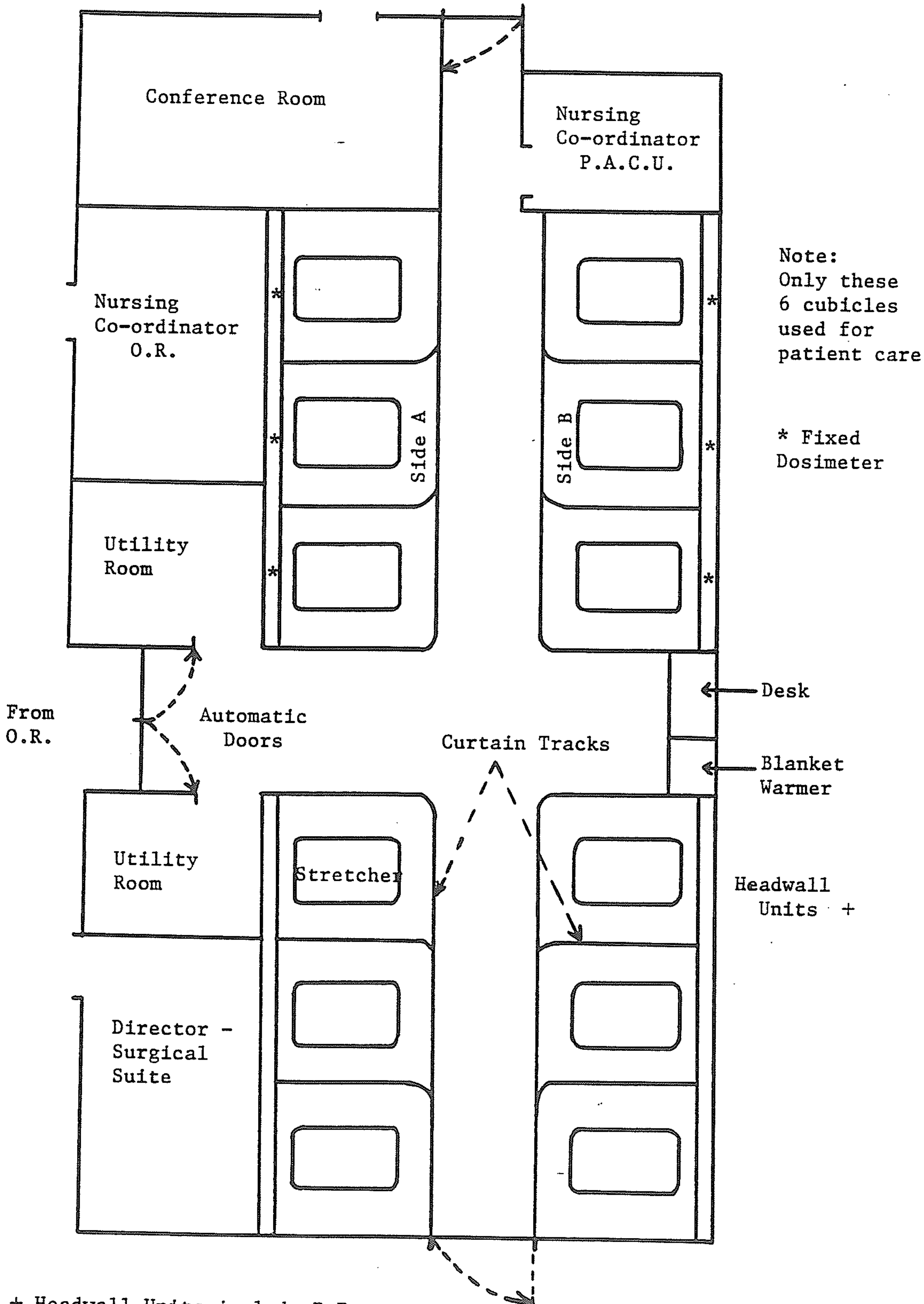
APPENDIX B

CONCEPTUAL FRAMEWORK



APPENDIX C

DIAGRAM OF P.A.C.U.



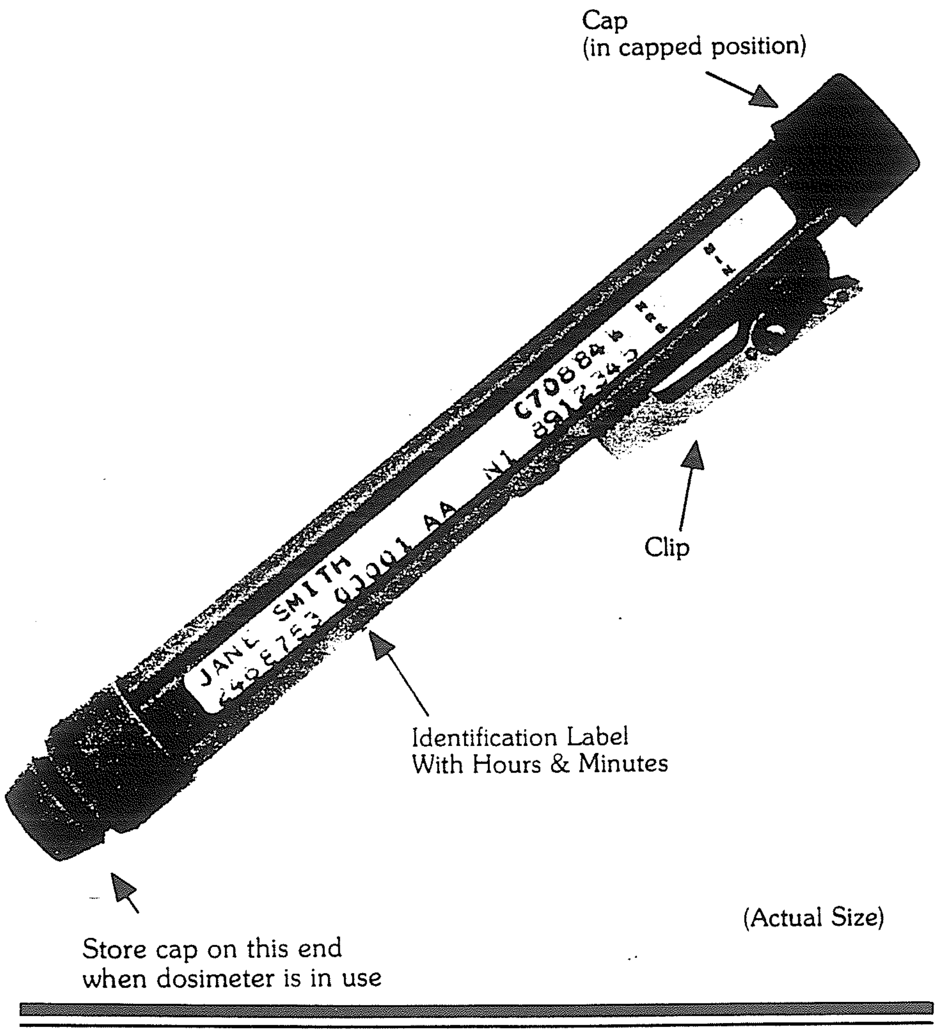
+ Headwall Units include B.P., Suction, Monitors, Scavenging System, Oxygen

APPENDIX D

NITROUS OXIDE DOSIMETER

NITROX™

Quick Reference Guide For Monitoring Personnel Exposures To Waste Nitrous Oxide



Landauer Tech/Ops

THE MEASURABLE DIFFERENCE IN PERSONNEL DOSIMETRY

APPENDIX E

CONSENT FORM

This consent form indicates that I,___________________________
(print name in full)
agree to participate in a study which measures the effect of an anaesthetic gas scavenging system on the quality of air in the Post-Anaesthetic Care Unit.

I understand that the study will be conducted by Mary Knight Kubasiewicz, RN, BScN, MN Candidate, of the University of Manitoba School of Nursing. The research will be supervised by A. Jope, PhD, Assistant Director, School of Nursing, University of Manitoba. I have been provided with a verbal and written explanation of the study, which fully described the commitment required of me as a participant in the study. I have had the opportunity to ask questions and feel that I can ask further questions at any time.

I realize that involvement in the study is voluntary, and that I can withdraw at any time without consequence. I have been told that the study is investigatory in nature, and that there are no direct personal benefits to me. I understand that the purpose of the study is to measure the effect of an anaesthetic gas scavenging system on the quality of air in the Post-Anaesthetic Care Unit.

I understand that I will be working in the P.A.C.U. during a two (2) week period when the anaesthetic gas scavenging system will be connected on some patients, and not connected on other patients, for the purposes of the study.

My signature on this page indicates that I consent to participate in the study. I realize that a summary of the study results will be available in the P.A.C.U. I am aware that if the results of the investigation are published, confidentiality of participants will be maintained. A photocopy of this completed consent form will be provided to me by the investigator.

______________ _____________________________________

Date Signature of Participant

______________ _____________________________________

Date Mary Knight Kubasiewicz, RN, BScN,
MN Candidate

APPENDIX F

DESCRIPTION OF THE STUDY

The Post-Anaesthesia Care Unit (P.A.C.U.), which is structurally identical on each side of the room, will be divided into side A and side B. Two nurses will be randomly assigned to work on each side of the room. Patients recovered on side A will have the scavenging system connected (this is the experimental intervention, or X). Patients recovered on side B will not be connected to the system (this is be the control group). Routine P.A.C.U. nursing care will be provided as usual to all patients according to individual needs.

The nurses will wear nitrous oxide dosimeters to assess the effect of the scavenging system on the quality of air in their breathing zone, by continuously measuring levels of nitrous oxide. The nurses will be randomly assigned each day to a numbered dosimeter. Dosimeters #1 and #2 will be worn for five days by staff working on side A, while #3 and #4 will be worn by those working on side B. There are several part-time nurses employed in the P.A.C.U., and only four nurses work each day, which means the same four nurses would not be available in a five day period. However, the random assignment of nurses to dosimeters enhances external validity, in that participant effects will be mediated.

In addition, dosimeters will be placed at strategic locations in the P.A.C.U. to measure levels of nitrous oxide in the ambient air (see Appendix C).

The first ten patients of each day (fifty patients per week) will be the source of waste anaesthetic gases. The study will run for two weeks, for a total of one hundred patients, fifty with the system, and fifty without. At the end of the first week, the sides of the room will switch, i.e. side B will now receive patients who have the scavenging system connected, not side A, and the study will be repeated. New dosimeters will used for the second week of the study, as they can only be used for forty hours (one week).

APPENDIX G

SAMPLE DOSIMETRY REPORT

ACCOUNT NO.	SERIES CODE	WEAR PERIOD	PREP. DATE	DOSIMETER RECEIVED	SUMMARY	NO. REPORT COPIES	PAGE NO.
0090000	AAA	WEEKLY	070984	070684		1	1

R. S. LANDAUER JR & CO.
SAMPLE REPORT
SCIENCE ROAD
GLENWOOD SCIENCE PARK
GLENWOOD IL 60425
PURCH ORDR# RSL0009

Landauer

a Tech/Ops company

R. S. Landauer. Jr. & Co.
2 Science Road
Glenwood. Illinois 60425-1586
(312) 755-7000

QUALITY CONTROL RELEASE
TST

CHEMICAL DOSIMETRY REPORT

PARTICIPANT I.D. NUMBER	NAME/LOCATION	SOCIAL SECURITY NUMBER	BADGE TYPE	AGENT	EXPOSURE GUIDE TWA	EXPOSURE HOURS UNCAPPED	EXPOSURE PPM-HOURS	EXPOSURE TWA	PREDICTED TWA	NOTE CODE	DOSIMETER NUMBER
	FOR EXPOSURE PERIOD	06/17/84 TO	06/23/84								
00001	TINA TURNBOLT	308-64-8416	N1	N20	25	9.0	339	38			9000
00002	EDGAR A PARTING	369-42-5671	N1	N20	25	8.8	1752	200			9001
00003	DENNIS BROWNIE	409-52-0443	N1	N20	25	8.8	824	94			9002
00004	BERNARD P FIFE	654-32-1234	N1	N20	25	24.7	10330	419			9003
00005	JOHN SMYTHE	802-58-0117	N1	N20	25	24.7	5615	228			9004
00006	LUCA BRAZZI	759-35-7375	N1	N20	25	36.0	M	M			9005
00007	KATHY LEWIS	769-51-9788	N1	N20	25	84.0	3525	42			9006
00008	RALPH KRAMDEN	484-89-9804	N1	N20	25	84.0	230	3		RU	9007
00009	BRIAN CARTELL	688-96-2660	N1	N20	25	.0	[redacted]	[redacted]		U	9008
00010	DEBBIE HARRIS	926-62-2043	N1	N20	25	40.0	1288	32			9009
00011	JOHN J HERNER	662-10-1776	N1	N20	25	40.0	555	14	36		9010
00012	DR. M HOWARD	900-56-7692	N1	N20	25	40.0	98	2	9	NT	9011
[redacted]	DR. L FINE	330-76-9519	N1	N20	25	60.0	1086	18	30	BR	9012
00014	JANICE BEST	776-92-0347	N1	N20	25	23.3	*****	9600		BN	9013
00015	MARY WILLIS	692-03-3127	N1	N20	25	20.0	19000	900			9014
00016	SARAH HAZELTON	553-37-9131	N1	N20	25	40.0	68256	1706		GT	9015
[redacted]	WALT MATTHEWS	219-76-9005	N1	N20	25	40.0	1156	29			9016
00018	CAROL BURLINGTON	621-97-6951	N1	N20	25	20.0	12000	600			9017
00019	JOAN RIVERSIDE	971-21-9759	N1	N20	25	20.3	M	M		PF	9018
00020	DAWN CROSS	357-37-6910	N1	N20	25	19.8	5143	260			9019
[redacted]	ERNEST T BASS	173-08-6494	N1	N20	25	40.0	1023	26	28		9020
00022	GINA DONALDSON	171-10-8560	N1	N20	25	40.0	555	14	36		9021
00023	FLOYD LAWSON	080-02-1958	N1	N20	25	40.0	1023	26	28		9022
00024	GEORGE CARLSON	111-71-9820	N1	N20	25	40.0	543	14	337		9023
00025	DAVID BRENBAG	100-28-2190	N1	N20	25	40.0	531	13	7		9024
00026	RICHARD STARKEY	010-01-1947	N1	N20	25	40.0	27000	700		TD	9025
00027	FRANK TRANSLEE	193-91-9420	N1	N20	25	40.0	1074	27			9026
00028	DUWAYNE KING	312-33-9754	N1	N20	25	40.0	350	9			9027
00029	SALLY MEADOWS	404-33-2975	N1	N20	25	40.0	389	10	36		9028
00030	EDWARD L NORTON	643-82-9751	N1	N20	25	40.0	215	5	7		9029
00031	JAMES MC CARTNEY	209-88-4273	N1	N20	25	40.0	397	10	50		9030
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)

NT – NO TIME LISTED – 40 HOURS ASSUMED
RESULT MAY BE HIGH IF HOURS WORN IS LESS
BR – WEAR PERIOD BEYOND CALIB RANGE
GT – GREATER THAN OR EQUAL
BN – DATA BEYOND NORMAL RANGE

RU – RETURNED UNCAPPED
U – UNUSED
BN – DATA BEYOND NORMAL RANGE
PF – PROCESSING FAULT

TABLE 1

Patient Age Data

Without Anaesthetic Gas Scavenging System

	PT 1	PT 2	PT 3	PT 4	PT 5	SUB-TOTAL
SIDE A						
DAY 1	32	17	19	39	34	141
DAY 2	17	28	46	18	40	149
DAY 3	16	21	15	25	37	114
DAY 4	10	64	37	77	27	215
DAY 5	6	34	23	70	30	163
					MEAN:	31.3
Years						
SIDE B						
DAY 6	21	70	42	33	25	191
DAY 7	20	33	22	40	22	137
DAY 8	49	49	27	34	25	184
DAY 9	36	59	40	62	28	225
DAY 10	35	63	34	33	56	221
				MEAN:	38.3 Years	

AGE DATA SUMMARY: DAYS 1 - 10 (WITHOUT SYSTEM)

RANGE: 6 - 77 Years

MEDIAN: 33 Years

MEAN: 34.8 Years

TABLE 2

Patient Age Data

With Anaesthetic Gas Scavenging System

	PT 1	PT 2	PT 3	PT 4	PT 5	SUB-TOTAL
SIDE B						
DAY 1	27	32	43	65	35	202
DAY 2	56	20	24	17	9	126
DAY 3	34	27	16	34	31	142
DAY 4	34	13	57	31	73	208
DAY 5	23	55	21	8	25	132
				MEAN:	32.4 Years	
SIDE A						
DAY 6	28	58	32	46	51	215
DAY 7	38	16	34	28	19	135
DAY 8	27	44	62	44	34	211
DAY 9	13	19	16	35	54	137
DAY 10	40	35	36	49	27	187
				MEAN:	35.4 Years	

AGE DATA SUMMARY: DAYS 1 - 10 (WITH SYSTEM)

RANGE: 8 - 73 Years

MEDIAN: 28 Years

MEAN: 33.9 Years

TABLE 3

Length of Anaesthesia in Minutes

Without Anaesthetic Gas Scavenging System

	PT 1	PT 2	PT 3	PT 4	PT 5	SUB-TOTAL
SIDE A						
DAY 1	45	87	24	49	50	255
DAY 2	37	46	158	23	143	407
DAY 3	46	62	50	38	47	243
DAY 4	39	62	41	62	57	261
DAY 5	58	57	42	40	40	237
				MEAN:	56.12 Minutes	
SIDE B						
DAY 6	40	100	55	18	28	241
DAY 7	71	101	30	80	17	299
DAY 8	25	34	42	38	73	212
DAY 9	37	80	23	127	27	294
DAY 10	74	52	21	32	19	198
				MEAN:	49.76 Minutes	

LENGTH OF ANAESTHESIA DATA SUMMARY: DAYS 1 - 10 (WITHOUT SYSTEM)

RANGE: 17 - 158 Minutes

MEDIAN: 46 Minutes

MEAN: 52.94 Minutes

TABLE 4

Length of Anaesthesia in Minutes

With Anaesthetic Gas Scavenging System

	PT 1	PT 2	PT 3	PT 4	PT 5	SUB-TOTAL
SIDE B						
DAY 1	38	43	72	29	106	288
DAY 2	36	33	65	37	17	188
DAY 3	73	52	52	27	30	234
DAY 4	47	38	32	58	42	217
DAY 5	45	82	42	33	41	243
				MEAN:	46.80 Minutes	
SIDE A						
DAY 6	97	30	40	23	60	250
DAY 7	27	36	36	46	29	174
DAY 8	30	78	31	71	41	251
DAY 9	32	95	25	32	82	266
DAY 10	94	37	35	43	43	252
				MEAN:	47.72 Minutes	

LENGTH OF ANAESTHESIA DATA SUMMARY: DAYS 1 - 10 (WITH SYSTEM)

RANGE: 17 - 106 Minutes

MEDIAN: 40.5 Minutes

MEAN: 47.26 Minutes

TABLE 5

PACU Time in Minutes

Without Anaesthetic Gas Scavenging System

	PT 1	PT 2	PT 3	PT 4	PT 5	SUB-TOTAL
SIDE A						
DAY 1	55	60	68	65	49	297
DAY 2	40	61	40	50	72	263
DAY 3	79	46	102	60	52	339
DAY 4	67	56	89	69	73	354
DAY 5	97	45	57	55	66	320
				MEAN:	62.92 Minutes	
SIDE B						
DAY 6	69	98	48	38	65	318
DAY 7	47	83	120	95	62	407
DAY 8	73	45	38	81	60	297
DAY 9	59	42	54	58	31	244
DAY 10	60	61	48	47	33	249
				MEAN:	60.60 Minutes	

PACU TIME SUMMARY: DAYS 1 - 10 (WITHOUT SYSTEM)

RANGE: 31 - 120 Minutes

MEDIAN: 60 Minutes

MEAN: 61.76 Minutes

TABLE 6

PACU Time in Minutes

<u>With</u> Anaesthetic Gas Scavenging System

	PT 1	PT 2	PT 3	PT 4	PT 5	SUB-TOTAL
SIDE B						
DAY 1	57	72	52	50	60	291
DAY 2	66	70	97	56	41	330
DAY 3	34	46	117	99	55	351
DAY 4	63	64	54	66	53	300
DAY 5	40	44	56	37	53	230
				MEAN:	60.08 Minutes	
SIDE A						
DAY 6	60	120	95	40	63	378
DAY 7	54	43	53	68	40	258
DAY 8	50	50	68	60	61	289
DAY 9	50	50	45	52	43	240
DAY 10	42	50	72	53	70	287
				MEAN:	58.08 Minutes	

PACU TIME SUMMARY: DAYS 1 - 10 (WITH SYSTEM)

RANGE: 34 - 120 Minutes

MEDIAN: 54 Minutes

MEAN: 59.08 Minutes

TABLE 7

Nurse Dosimeter Data

DOSIMETER NUMBER	SCAVENGER SYSTEM	WEEK	SIDE	HOURS NOT CAPPED	PPM	TWA
1	Without	1	A	22.1	129	6
2	Without	1	A	18.3	0	0
6	With	1	B	23.8	48	2
7	With	1	B	22.4	0	0
11	Without	2	B	20.3	37	2
12	Without	2	B	21.0	90	4
16	With	2	A	20.5	97	5
17	With	2	A	19.0	59	3

LEGEND:

DOSIMETER NUMBER
SCAVENGER SYSTEM - Presence or absence of scavenging system
WEEK - Week 1 or 2 or data collection
SIDE - Side of the PACU where nurse was assigned to work
HOURS NOT CAPPED - Hours the dosimeter was exposed
PPM - Parts per million exposure according to dosimeter number
TWA - Time weighted average according to dosimeter number

TABLE 8

Cubicle Dosimeter Data

DOSI #	SCAV	WEEK	SIDE	CUB	HOURS NC	FREQ	TOTAL LOA	TOTAL PACU	PPM	TWA
3	w/o	1	A	6	26.5	13	712	851	42	2
4	w/o	1	A	5	25.8	10	600	584	69	3
5	w/o	1	A	4	25.5	2	91	138	0	0
8	w	1	B	1	28.8	11	477	606	43	2
9	w	1	B	2	27.3	12	624	786	0	0
10	w	1	B	3	27.0	2	69	110	47	2
13	w/o	2	B	1	26.9	13	667	803	19	1
14	w/o	2	B	2	27.1	9	458	507	67	2
15	w/o	2	B	3	22.3	3	119	205	0	0
18	w	2	A	6	26.6	16	729	984	0	0
19	w	2	A	5	23.8	8	404	405	32	1
20	w	2	A	4	22.8	1	60	63	47	2

LEGEND:

DOSI # - Dosimeter number
SCAV. - Presence or absence of scavenging system
WEEK - Week 1 or 2 of data collection
SIDE - Side of the PACU where dosimeter was located
CUB - Number of cubicle to which dosimeter was assigned
HOURS NC - Hours the dosimeter was not capped, or exposed
FREQ - Number of times a cubicle was used
TOTAL LOA - Cumulative length of anaesthesia in minutes for patients in cubicle specific to each dosimeter
TOTAL PACU - Cumulative length of time in PACU per dosimeter
PPM - Parts per million exposure according to dosimeter
TWA - Time weighted average according to dosimeter number