



Management of Waste Anesthetic Gases

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Introduction

The Occupational Safety and Health Act of 1970 emphasized the need for standards to protect workers from potential hazards to health and safety that may exist in the work place. Criteria for a “Recommended Standard for Occupational Exposure to Waste Anesthetic Gases and Vapors” was developed in 1977 by the National Institute for Occupational Safety and Health (NIOSH) and published by the U.S. Department of Health Education and Welfare. This document was designed to assist operating room workers in developing their own standards for minimizing the risk of elevated trace gas exposure, and it continues to serve as a guiding resource for minimizing risk to healthcare workers. Official standards, however, for environmental control of waste anesthetic gases have not been established by the federal government.

In 1988, NIOSH published “Guidelines for Health Care Workers,” Publication number 88-119, which offers additional guidance to hospitals, anesthesia professionals, and other workers. In response to the publications of NIOSH in 1977 and 1988, the American Dental Association, the American Hospital Association, and the American Society of Anesthesiologists developed and published supplemental guidelines and recommendations to improve the management of waste gas. The U.S. Department of Labor, under the direction of the Occupational Safety and Health Administration (OSHA), continues to assist healthcare workers in learning about potential risks.

In 1991, the American Association of Nurse Anesthetists (AANA) surveyed a group of its committee members and program administrators of nurse anesthesia schools to determine the level of concern regarding exposure to waste anesthetic gases. More than half of those surveyed responded that they were “very concerned” about potentially harmful effects of prolonged exposure to elevated trace concentrations of waste gases. The results of that survey supported the need for increased education and training to promote proper use of waste gas scavenging systems, surveillance of exposure levels, and application of routine work practices that minimize unnecessary exposure to waste gases.

In 1992 and again in 2000, OSHA developed a revised guideline for the management of waste anesthetic gases and has distributed it to professional organizations for review and comment. The AANA responded to OSHA by identifying the needs of Certified Registered Nurse Anesthetists (CRNA), as defined by the survey results.

Multiple studies have been conducted about the risk of exposure to anesthetic agents, including hemopoietic studies; behavioral assessment studies; cellular studies; and animal studies on the effects of anesthetic agents on fertility, carcinogenicity, teratogenicity, and reproduction. Two general areas of research are found in the literature: epidemiological studies on medical and dental workers, and animal studies on the effects of anesthetics.

The use of prospective studies and carefully designed research protocol is encouraged, as the continuing assessment of this problem is both appropriate and practical. Until conclusive evidence is available, a responsible approach to worker health and safety dictates that any exposure to waste and trace gases should be kept to the lowest practical level. Thus, certain practices and procedures shown to offer an appropriate margin of safety to anesthesia providers are presented in this monograph.

Key Terms and Definitions

Allowable leak	Allowable leak is defined as the maximum leakage of the patient circuit assembly, including the absorber, inspiratory, and expiratory valves; adjustable pressure limiting (APL) valve; breathing tubes; Y-piece; and right angle connector, if present, and shall not exceed 300 mL/min when the patient circuit is pressurized to 30 cm H ₂ O.
Gas	Gas is defined as the fluid form of a substance that can expand indefinitely and fill its container.
Non-allowable leak	Non-allowable leak is defined as any leakage in excess of 300 mL/min in the patient circuit assembly.
Occupational exposure	Occupational exposure is defined as any contact with any inhalation gas or anesthetic agent that escapes into anesthetizing locations or is emitted into adjacent areas near anesthetizing locations, in the course of normal work operations.
Patient circuit	Patient circuit is defined as all components that extend from the common gas outlet to the patient mask or tracheal tube, including the carbon dioxide absorber, inhalation and exhalation check valves, breathing circuit and Y-piece, APL (“pop-off”) valve, absorbent canister(s), ventilator, and all accessories added to the breathing circuit, including the waste gas interface scavenging valve and components.
Scavenging	Scavenging is defined as the process by which waste anesthetic gases flowing from the patient circuit are collected, controlled, and evacuated from the work place to reduce ambient concentrations of agents or gases.
Shall	Shall denotes a mandatory consideration in order to meet the intent of these recommendations.
Should	Should denotes a desirable consideration in order to meet the intent of these recommendations.
Trace gas	Trace gas is defined as any substance present in the atmosphere of the work environment in a concentration exceeding the allowable percentage as defined in the NIOSH criteria for a recommended standard.
Trace gas concentrations	Trace gas concentrations are measured and expressed in parts per million (ppm) and represent a volume-to-volume relationship. Thus, 100% of any gas is 1 million ppm; 1% of a gas is 10,000 ppm. Measurements are determined over an 8-hour period and averaged over time to reflect the average trace gas concentration. The allowable level of exposure using a time-weighted average is 25 ppm of nitrous oxide and 2 ppm of a halogenated agent.
Vapor	A vapor of an anesthetic agent is the gaseous form of that liquid, and once the volatile drug is vaporized it behaves as a gas. For practical purposes, use of the word “gas” in this monograph shall refer to both gases and vapors used during general anesthesia.
Waste gas	Waste gas includes all fugitive anesthetic gases and vapors that are released into anesthetizing locations and recovery areas. Waste gas from an anesthesia machine delivery system may be composed of oxygen; carbon dioxide; nitrous oxide; nitrogen; helium; vapors of volatile anesthetic agents such as halothane, enflurane, and isoflurane; desflurane and sevoflurane; or any other agent or gas collected within and evacuated from an anesthesia or analgesia delivery system.
Waste gas interface valve	Waste gas interface valve is defined as that portion of the scavenging system that provides positive and negative pressure relief and may provide a reservoir capacity. The interface valve may be an independent device or an integrated part of the waste gas scavenging system.

Waste gas scavenging system	Waste gas scavenging system is defined as a device that collects gas from the patient circuit and removes excess anesthetic gases and vapors that are released from the equipment used or are exhaled by the patient.
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Effective Management of Waste Gases

Factors that Influence Trace Gas Concentrations

Elevated levels of trace gas are associated with two major factors; inappropriate work practices that alters the efficiency of the interface valve and the integrity and function of the facility's ventilation system. To manage waste anesthetic gases appropriately, it is essential that all anesthesia professionals be knowledgeable about the following:

- Sources of leaks that may contribute to excess trace gas concentrations within anesthetizing locations and how they may be detected and corrected.
- Function and performance of the components in the anesthesia delivery system.
- The facility program for measuring and monitoring levels of waste gas in the anesthetizing location.
- Work practices and techniques commonly known to help reduce the concentration of trace anesthetic gases present in the work environment.
- Potential effects of prolonged exposure to waste anesthetic gases.
- Regulatory and accrediting agency guidelines aimed at minimizing operating room workers' exposure to waste anesthetic gases.
- Recommendations from professional organizations.

Elements of an Effective Waste Gas Removal Program

Anesthesia professionals are responsible for preuse testing of the anesthesia delivery system according to the FDA and manufacturing recommendations, which include the integrated waste gas scavenging system. Anesthesia professionals are also required to adjust gas flow through the scavenging system at select times during each procedure, as part of their routine practice. To comply with the OSHA guidelines, anesthesia professionals are reminded that the following recommendations developed, in part, in 1977 and modified in 1988 are endorsed by the AANA and include, but are not limited to, the following requirements:

- Waste gas scavenging systems shall be used for evacuating waste anesthetic gases from any anesthetizing location.
- Waste gas scavenging systems shall be operated and maintained according to the manufacturer's recommendations.

Hospitals and other health care facilities that provide anesthesia services shall also meet key conditions of the OSHA guidelines by recognizing that:

- Anesthesia delivery systems must be inspected and tested by a factory-trained service provider for performance and safety on a quarterly basis or as recommended by the manufacturer to ensure that leaks are minimized, in keeping with the criteria set forth by OSHA. Recommended limits set forth by NIOSH should be considered a guide to the limits of exposure, and every effort shall be made to minimize total exposure for all personnel as much as possible.
- No worker should be exposed to more than an average of 2 ppm over an 8-hour period of any halogenated agent, which includes but is not limited to halothane, enflurane, and isoflurane.
- Measurements shall be reported on the basis of a time-weighted average over 8 hours, not on a single sample.
- No worker should be exposed to more than 25 ppm of nitrous oxide, measured over an 8-hour period, as a time-weighted average. Each facility shall inspect and test the operation and performance of the central vacuum system on a quarterly basis or in accordance with the facility's policy to ensure the adequacy of the vacuum source.
- Each facility shall inspect and test the operation and performance of the ventilation and air conditioning system used in the physical plant at regular intervals to ensure that complete room air exchanges occur at a rate of 15-21 times-per-hour or more.
- Each facility should provide or make available a service whereby the levels of trace concentrations of waste gases are measured on a quarterly basis in each anesthetizing location and cylinder storage area.

- Each facility should make the records of environmental sampling and test results available to all workers who are subject to job-related exposure to waste anesthetic gases.
- Each facility shall implement a medical surveillance program for all workers exposed to waste anesthetic gases.
- Each facility shall implement an information program that identifies the potential hazards of excessive exposure to waste anesthetic gases and complies with the 1990 OSHA requirement that defines an employee's "right to know".
- Each facility shall provide training for workers to help them recognize, understand, and reduce the risks of unnecessary exposure to trace gases in anesthetizing locations.
- Each facility shall devise a mechanism to identify and record the occurrence of injury or illness related to exposure as required by OSHA record keeping regulations.

Common Sources of Leaks in the Anesthesia Delivery System

High pressure leaks typically occur in the cylinder gas supply system. Low pressure leaks commonly occur in the patient circuit and its components, which include but are not limited to the carbon dioxide absorber, APL valve, inhalation and exhalation check valves, gas analysis sensors, tracheal tube or mask, and connections to accessory devices such as a humidifier, temperature probe, or PEEP valve.

Leaks also may occur where the supply hose connects to the wall outlet and where it connects to the anesthesia delivery system. Therefore, gas supply hoses shall be positioned to prevent strain on the fittings, constructed from factory recommended supply-hose materials, and manufactured for high-pressure gas flow and minimal kinking.

Leaks that occur between the fresh gas inlet on the back of the machine and the common gas outlet to the absorber often result from inappropriate installation of calibrated vaporizer(s) or from misalignment of a vaporizer on its manifold. This source of leak is readily detected during the preuse checking procedure and must be corrected prior to each machine use.

Dust particles often prevent a leak-tight seal when individuals reassemble the canister(s) in the carbon dioxide absorber. The exhaust from an end-tidal carbon dioxide (CO₂) monitor shall also be connected to the waste gas scavenging system.

Scavenging Systems

The purpose of a waste gas scavenging system is to evacuate anesthetic waste gases from the anesthesia machine and out of the work environment. When a vacuum source is attached to the waste gas interface valve, the system is described as an active waste gas scavenging system. When a vacuum source is not used, the system is described as a passive waste gas scavenging system.

Waste gas evacuation is required for every type of breathing circuit configuration because the anesthesia machine typically delivers more fresh gas flow than the patient needs. To compensate for continuous flow and to minimize pollution in an active scavenging system, the waste gas interface valve must be visually monitored and adjusted on a regular basis whenever fresh gas flow is changed during the procedure or whenever the facility-wide demand on the vacuum supply increases or decreases its capacity to provide suction.

These periodic adjustments are routinely required, except during low-flow, closed system techniques that employ a fresh gas flow of approximately 500-1,000 mL and a dedicated vacuum source. Low-flow techniques require only occasional adjustments when a higher flow is intentionally used or when the oxygen flush valve is activated. Adjusting the vacuum on a regular basis regulates the flow of gas through the waste gas scavenging system and is necessary to prevent discharge of waste gas into the operating room and minimize excessively high or low pressure fluctuations in the patient circuit that could influence the airway pressure.

Appropriate waste gas evacuation involves collection and removal of waste gases, detection and correction of leaks, consideration of work practices, and an effective room ventilation system. A machine-specific interface valve must be integrated with a facility's system for gas removal. The interface valve permits excess gas to be collected in a reservoir bag and regulates the pressure within the bag. A facility's system receives anesthetic gases from the interface valve and reservoir bag and empties them into the outside atmosphere.

The interface valve consists of a manifold with four ports and two relief valves. Figure 1 shows the flow of waste gases from the anesthesia ventilator and the breathing circuit as they enter the intake ports of the interface valve. This drawing shows the pathway of gas flow in an active scavenging system that uses a facility's vacuum source (wall suction) for gas disposal.

As gas is pulled through the suction nipple, located on the right of the drawing in Figure 1, it flows through the manifold and past the two relief valves. The top relief valve limits positive pressure, and the bottom valve manages negative pressure. A 3-L bag is attached in the model illustrated.

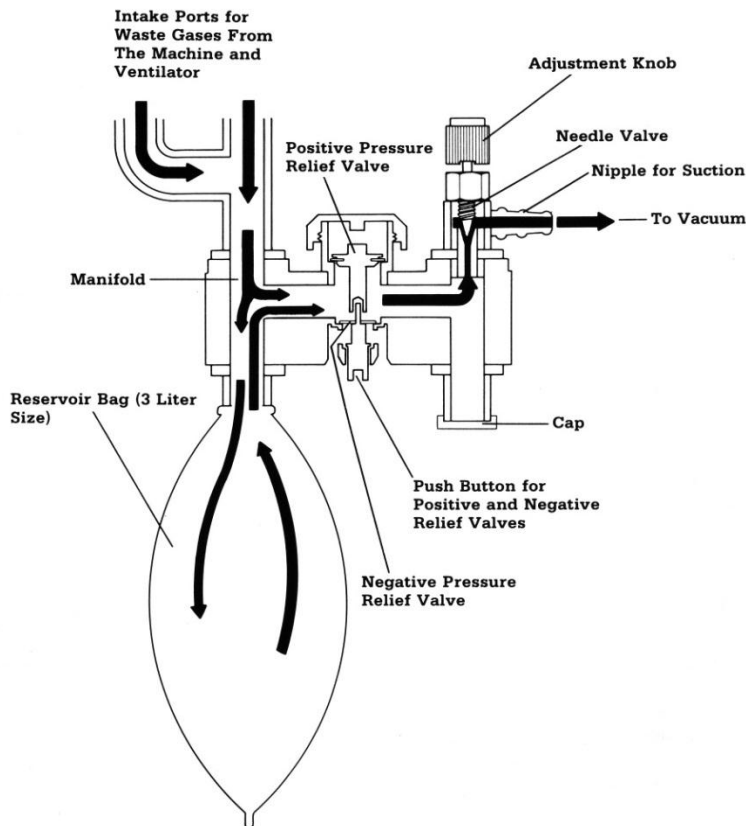


Figure 1: An active scavenging system—gas from the anesthesia ventilator and the patient's breathing circuit enters the intake ports, flows through the manifold, passes the positive and negative relief valves, and flows out through the vacuum source.

When a bag is not used as the reservoir, a block of space is designed into the frame of the anesthesia machine to serve as a reservoir for waste gases. When more flow is passing into the manifold than the vacuum can remove, waste gas is temporarily stored in the reservoir bag or the block provided in the housing of the machine.

A passive scavenging system for waste gas evacuation, shown in Figure 2, uses the facility's air conditioning ducts instead of the vacuum system to dispose of waste gas. In this configuration, flow of waste gas through the manifold is basically the same as in the active system. The pressure exerted by the gas is also controlled by positive and negative relief valves. In a passive system the adjustment knob must remain in the down position to close the needle valve and a 19mm corrugated hose is used to connect the interface valve with the air intake duct of the air conditioning system. A passive system (unlike an active system) is not connected to a vacuum source and does not need to be adjusted on a regular basis.

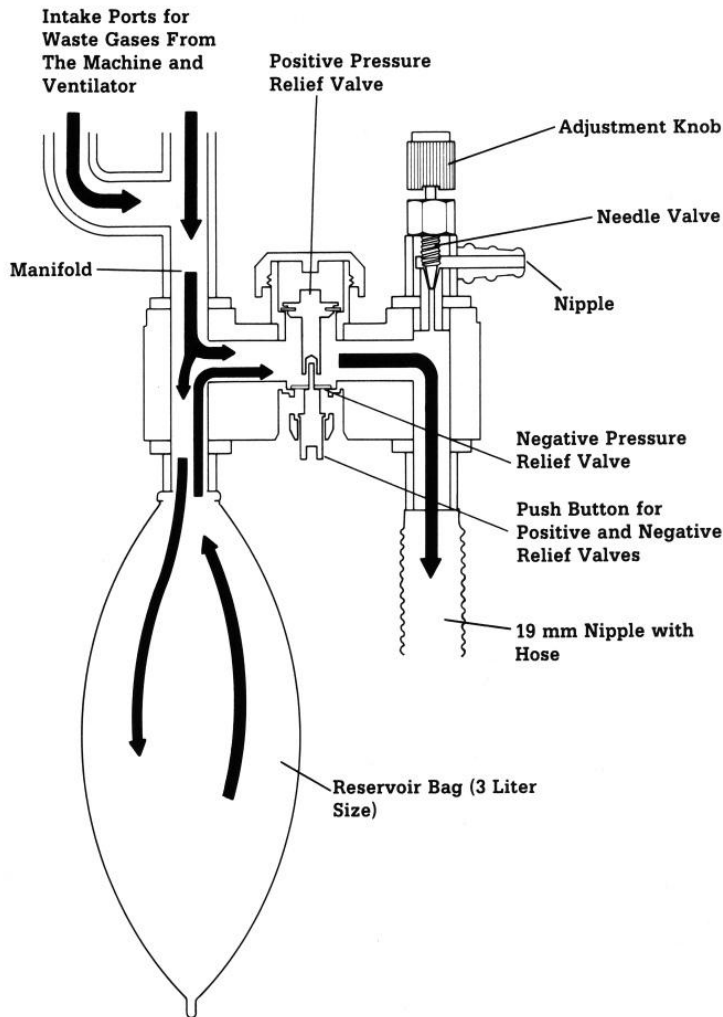


Figure 2: A passive scavenging system—gas flows into the manifold and out through the interface valve to the air intake duct of the air conditioning system via a 19-mm corrugated hose. Note the adjustment knob is in the down position and the needle valve is closed to prevent waste gas from escaping into the ambient air.

Adjusting Flow Rates Through the Scavenging System

The rate at which gas flows through the interface valve in an active system is controlled by turning the adjustment knob of the needle valve. Adjusting the needle valve alters the flow of waste gases into the vacuum source. Adjusting the needle valve does not affect the vacuum level provided by the wall outlet. In scavenging systems that employ a reservoir bag, adjustments are regularly made to prevent the bag from overdistingending. In the ideal situation, flow rate should be controlled to maintain the volume in the

reservoir bag between empty and half-filled. In machines that use a portion of the frame as the reservoir, a conveniently placed indicator alerts the clinician when the flow is in excess of the vacuum source.

If the vacuum is insufficient in an active system and the reservoir bag is allowed to distend, the positive pressure relief valve on the interface manifold opens to vent the accumulated exhaled gas into the room. For example, when the flush valve is activated, 35-75 L of fresh gas (oxygen) may be added to the circle system to supplement the continuous flow of oxygen from the flowmeter. If the reservoir bag is allowed to distend to more than half-filled and the adjustment knob is not turned to compensate for the added flow of waste gas through the manifold, anesthetic gases escape through the relief valve and pollute the anesthetizing area.

If the flow of gas drawn out by the vacuum is too high and the bag collapses, the negative relief valve opens to draw room air into the manifold. During routine clinical use, the contour of the bag is visually examined to monitor its distension and the waste gas system is adjusted as needed. In active scavenging systems, any unused port on the waste gas interface valve and manifold must be capped, or the vacuum will simultaneously draw in room air through the open port.

The rate of flow in a passive waste gas system is determined by four factors:

- Fresh gas flow through the anesthesia machine.
- Volume of gas stored in the reservoir bag or in the block on the frame that is dedicated to waste gas collection.
- Diameter of the hose that moves the gas away from the machine.
- The resistance of the hose between the scavenging system and the air circulation vent.

In both active and passive systems, any obstruction in the hose substantially reduces the flow of gas through it. If the flow is insufficient and the reservoir bag becomes distended, the positive pressure relief valve opens and waste gas is intermittently discharged into the anesthetizing area. To prevent waste gas from being continuously discharged into ambient air, any unused port must always be capped.

Clinical Considerations

Excessive positive pressure conditions can develop when an anesthesia machine or any other device is unintentionally rolled onto the waste gas evacuation tubing and obstructs the flow of waste gas. Blood, fresh frozen plasma, crystalloid solutions, and even tincture of benzoin have been unintentionally spilled onto the interface manifold and dried, effectively sealing the positive and negative relief valves. Adhesive tape has also been applied across the manifold resulting in the unintentional limitation of function of both relief valves, rendering them closed.

Incorrect assembly of the gas disposal hose connected to the wall vacuum source or improper connections between the gas disposal hose and the air conditioner duct may also impede the flow of gases away from the patient circuit. Generally, inappropriate installation, for whatever reason, can result in the following:

- Inadequate gas flow in an active scavenging system.
- Excessive resistance in a passive scavenging system.

When the positive pressure relief valve is stuck in the closed position, positive pressure may be exerted against the diaphragm of the APL valve, or “pop off” valve, and be transmitted to the patient circuit. Depending on the design and operating specifications for each model of anesthesia machine, the APL valve may not relieve pressure until it reaches its high pressure relief setting, which ranges from 60-80 cm H₂O pressure.

If the patient is unable to exhale as needed, the airway pressure gauge and monitor will display a suddenly elevated or gradually sustained airway pressure. If this condition develops, immediately check the positive pressure relief valve on the waste gas interface manifold to be certain it is not occluded. Negative pressure may develop in the patient circuit when too much vacuum is present and the vacuum flow-rate becomes excessively high. To prevent negative pressure from being referred to the patient circuit and the possible removal of both waste gas and fresh gas from the breathing system, adjust the knob on the interface valve to limit the vacuum supply.

Inappropriate performance of either relief valve may result in equipment failure or a potential complication to a patient. Thus it is important to visually inspect the valve stem that is common to both the positive and negative relief valves before each case to ensure that the stem is not covered with debris or in any way fixed in the closed position. Protective coverings, plastic bags, and other materials commonly found in anesthetizing locations must not be permitted to touch the relief valve, limit the valve from entraining room air, or occlude the movement of the valve stem. By ensuring that both valves move freely and can open to the atmosphere at all times, problems of elevated and subambient pressures in the patient circuit are minimized.

Preuse Testing and Verification of the Waste Gas Interface Valve

In order to verify that the waste gas interface valve is functioning properly, conduct the following inspection and testing procedure or its equivalent, before each case:

- Pressurize the breathing circuit using the oxygen flush valve.
- Occlude the patient end of the breathing circuit. Fill the rebreathing bag. Fully open the APL valve and verify that the breathing circuit pressure does not rise above 3 cm of water with a 3 L/min flow on the flowmeter.
- Place your index finger on the bottom of the negative pressure relief valve and push the valve stem up to physically verify that it moves freely.
- Inspect all surfaces for debris and clean them as recommended, using an approved detergent identified by the manufacturer.

Ensure that component parts and hoses used for waste gas evacuation meet the American Society for Testing and Materials minimum standard for safety and performance. Avoid using nonapproved substitutions for any parts.

Operating room pollution has also been linked to the use of hoses and caps not designed for waste gas removal.

Reducing Waste Anesthetic Gases in Ambient Air

The concentration of waste anesthetic gases in a mixture of room air will vary greatly depending on the rate of air exchanges provided by the ventilation system in the room, the integrity and capability of a facility's central vacuum source, the implementation of appropriate preventive maintenance procedures, and the frequency and efficacy of preuse leak testing of anesthesia machines, patient ventilators, and all accessory components installed within the anesthesia system.

Operating rooms, delivery rooms, and other hospital locations where surgery and anesthesia services are provided should conform to the guidelines established by the American Institute of Architects, which identify the standard of a minimum of 15-21 air exchanges per hour for existing hospitals and medical facilities. Each facility should evaluate the efficiency of air flow at regular intervals, document its findings, and inspect air flow filters to ensure that they are not clogged with debris.

Preventive maintenance programs for anesthesia machines, patient ventilators, and components of life support or life-sustaining devices, such as patient circuits and waste gas scavenging systems, shall be established to follow the preventive maintenance plan recommended by the original manufacturer of each device. Preventive maintenance procedures shall be performed by a device-specific, factory-trained service technician on a quarterly basis or more often, as needed.

Waste gas scavenging systems have been reported to reduce pollution tenfold. However, high levels of waste anesthetic gases may result whenever systems are defective, not used, improperly used, improperly adjusted, or poorly maintained. As noted in the Food and Drug Administration's (FDA) Anesthesia Apparatus Checkout Recommendations of 1986 and its revision initiated in 1992, the flow of gas through the interface valve must be adjusted during each procedure to compensate for excessively high or low pressure fluctuations in the waste gas, manifold, and reservoir bag. An empty bag will permit the vacuum source to entrain room air while an overinflated bag will allow waste gas to escape into the work environment.

Monitoring Trace Gas Concentrations

Monitoring trace gas concentrations should always include regular sampling and measurements of the area. Measurements should be conducted by a fully trained and credentialed individual skilled in the sampling and measurement techniques selected by the anesthesia service and the facility. Personal sampling is also recommended using a gas and vapor diffusion sensitive badge, meter, or other acceptable sampling technique.

Measurements of trace gas concentrations, levels far below those needed for clinical anesthesia, are expressed in parts per million and represent a volume-to-volume relationship. This, 100% of any gas is 1 million ppm; 1% of any gas is 10,000 ppm.

Average trace gas concentrations have been reported from multiple studies of rooms without gas scavenging systems and show:

- Halothane levels of 1-10 ppm in anesthetizing locations. PACU units average 0-8.2 ppm of halothane.
- Nitrous oxide levels from 400-3000 ppm. In PACU units, nitrous oxide trace gas ranges from 15-1660 ppm.
- Enflurane levels from 5-46 ppm in anesthetizing locations.

Trace gas sampling should be conducted in anesthetizing locations during peak activity periods and shall be scheduled to track routine gas concentrations and determine if exposures are present after liquid spills.

Repetitive sampling should take place on a prescribed schedule. If a problem exists, sampling should occur to ensure a problem is resolved. Complete records should be kept of all sampling methods, locations, dates, analytical methods, and concentrations of trace gases measured. Records should be kept for 5 years. If levels are above the prescribed limit, factory-trained service providers should assist in identifying the cause of the problem, and corrective actions should be implemented and documented. Results of samplings should be made available to exposed employees and are commonly posted for employees to review in an appropriate location in each anesthetizing area.

Disposal of Anesthetic Agents

Healthcare professionals responsible for administering inhaled anesthetic agents are also responsible for coordinating and directing appropriate handling procedures in all anesthetizing locations. It is generally accepted that small amounts of liquid anesthetic agent spilled in a well-ventilated room will evaporate before cleanup procedures can be implemented. When large spills occur - for example, when one or more bottles of a liquid agent break - specific cleaning and containment procedures are necessary and appropriate disposal is required.

According to the manufacturer's Material Safety Data Sheet for enflurane and desflurane, disposal of these waste liquids should be handled in accordance with rules and regulations set forth by the Environmental Protection Agency (EPA) as criteria for use with hazardous waste. The identifying code number, D022, is used for both liquids and describes for the waste handling contractor why the material is being classified as hazardous. This classification is applied to enflurane and desflurane only because a byproduct of the manufacture of these products includes a trace amount of chloroform. Isoflurane and halothane do not contain trace amounts of chloroform or any other regulated byproducts and are not considered hazardous wastes under EPA regulations.

To minimize exposure to all liquid anesthetic agents during routine use and to limit exposure to waste liquid agents during disposal procedures, the following general guidelines are recommended by the manufacturer for liquid anesthetic agents either drained and discarded from a vaporizer or cleaned up from a spill:

- Collect the liquid spilled and the absorbent materials used to contain a spill in a glass or plastic container. Tightly cap and seal the container and remove it from the anesthetizing location. Label the container to clearly indicate its contents.
- Transfer the sealed containers to a designated waste disposal service area that handles chemical waste.
- Healthcare facilities that own or operate medical waste incinerators may dispose of waste anesthetics by appropriate incineration methods. The health care facility is responsible for verifying that individual operating permits for incineration sites allow burning of anesthetic agents at each respective site.
- Empty anesthetic bottles are not considered to be regulated waste. They may be discarded with ordinary trash or recycled.

Appropriate Response to Agent Spillage

Small volumes of liquid anesthetic agents, such as halothane, enflurane, and isoflurane evaporate readily in well-ventilated anesthetizing locations and may dissipate before any attempts to cleanup or collect the liquid are initiated. Desflurane boils at room temperature and dissipates even more rapidly. Sevoflurane boils at 58.6 degrees centigrade.

Spills of larger volumes should be absorbed using an absorbent material, sometimes called a sorbent, that is designed for cleanup of organic chemicals. "Spill pillows" (commonly used in hospital laboratories), vermiculite, and carbon-based sorbents are some of the materials commercially available and regularly used for this purpose.

Sorbents that have been saturated with enflurane or desflurane should be managed as an EPA hazardous waste material due to their trace concentrations of chloroform. The waste material should be placed in a container, tightly sealed, properly labeled, and disposed of with other chemical wastes sent to a facility's incinerator or removed by a chemical waste contractor. A sorbent that is saturated with halothane or isoflurane is not a hazardous waste material but should be discarded in a similar manner. When a large spill occurs, it is important to repeat the trace gas sampling procedure to ensure that the spill has been effectively contained.

Other Work Practices that Minimize Exposure

Simple deficiencies are often the most overlooked causes of elevated trace gases in anesthetizing areas. A poor mask fit and an improperly inflated tracheal tube cuff are two examples of work practices that increase waste gas exposure for all workers. Lack of awareness and inattention to detail are often the most causative factors of operating room pollution.

When attempting to minimize the concentration of waste anesthetic gas in the work environment, it is important to follow these established clinical practices:

- Disconnect oxygen and nitrous oxide pipeline hoses from the wall outlets and close cylinder valves at the end of the workday to reduce the levels of nitrous oxide in the ambient air and to conserve gases.
- Never sniff an anesthetic agent. The odor threshold for liquid anesthetic agents has been reported to be approximately 50 ppm, which represents 25 times more than the recommended exposure limit. Intentionally inhaling an agent, even briefly, is an unnecessarily high exposure and should be avoided.
- Conduct all leak tests using oxygen flow only.
- Avoid turning on nitrous oxide or any halogenated agent until the face mask is securely attached to the patient's face.
- Avoid unnecessary disconnection of the breathing circuit.
- Turn off nitrous oxide and any halogenated agent, when feasible, and empty the rebreathing bag into the waste gas scavenging system before disconnecting the breathing circuit from the patient.
- Administer 100% oxygen, when possible, before removing the airway maintenance device.
- Avoid breathing anesthetic agents exhaled by patients as they emerge from general anesthesia.
- Avoid spilling the anesthetic agent when filling calibrated vaporizers. Turn to off position when not in use.
- Install key-fill models of calibrated vaporizers, where possible, on all anesthesia delivery systems.
- Connect Bain Circuits and other nonbreathing patient systems to specialized waste gas disposal adapters recommended by the manufacturer and designed for waste gas applications.

Conclusion

The scientific literature includes many reports of a possible link between exposure to waste gases and illness among select groups of healthcare workers. The findings to date, however, do not validate a direct cause and effect relationship. Until more information is derived from continuing study, the most appropriate practice is to be better safe than sorry and minimize the levels of exposure for all workers.

The responsibility for complying with safe work standards is shared by employers, workers, the federal government, manufacturers, and local enforcement agencies. The efforts of anesthesia professionals to limit exposure levels for themselves and their co-workers are the single most important factor of all. This responsibility is clearly fulfilled when anesthesia professionals ensure the scavenging system works properly, make all routine adjustments to flow through the scavenging system in a timely manner, follow EPA regulations and recommendations for disposal of inhalation anesthetic agents, and pay attention to the operational and maintenance procedures identified by the manufacturers of anesthesia machines and waste gas scavenging accessories.

If, over time, the risk factors of exposure to trace gases prove to be minimized or reduced due to improved work environment practices, and better health of anesthesia professionals can be conclusively measured, the preventive actions taken will have been rewarded. If a cause and effect relationship is never established, and further data suggest the risk factors are even less serious than have been suggested, the prudent management of waste gas exposure will still be respected as an appropriate means of pollution control. Until further study offers a logical and reasonable body of data to redirect the actions of anesthesia professionals, these prudent and careful practices are necessary for the protection of all workers as a practical and available means to reduce the risk of potential problems associated with chronic exposure to waste anesthetics.

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