

Commentary and recommendations on control of waste anesthetic gases in the workplace

Introduction

1. Recommendations for the control of waste anesthetic gases in the workplace apply to the use of these agents in most common, indoors sites of delivery, such as operating rooms, or research laboratories. Outdoors situations are briefly addressed at the end of this document.

2. In 1996, the American College of Veterinary Anesthesiologists published its first commentary and recommendations on control of waste anesthetic gases in the workplace. As then, conflicting evidence continues to exist in the scientific literature about the effects of trace levels of anesthetic gases on the health and performance of operating room personnel, such that a direct cause-and-effect relationship between occupational anesthetic gas exposure and occupational health problems remains to be firmly established. Until conclusive evidence is available, the responsible approach to worker health and safety remains to minimize exposure to waste and trace gases to the lowest practical level.

3. In the United States, official standards for environmental control of waste anesthetic gases have not been established by the federal government. The Occupational Safety and Health Administration (OSHA) workplace standards do not specifically address waste anesthetic gases. ¹ Twenty-five states, Puerto Rico and the Virgin Islands have OSHA-approved State Plans and have adopted their own standards and enforcement policies. For the most part, these States adopt standards that are identical to Federal OSHA. However, some States have adopted different standards or may have different enforcement policies; individuals should familiarize themselves with the standards applying to their workplace, which can be found at: <https://www.osha.gov/dcsp/osp/index.html>.

4. While OSHA provides guidelines for workplace exposures to anesthetic gases, "these guidelines are not a new standard or regulation, and they create no new legal obligations. The guidelines are advisory in nature, informational in content, and are intended to assist employers in providing a safe and healthful workplace through effective prevention programs adapted to the needs of each place of employment". Further, the OSHA guidelines are not intended to address issues related to patient care. ²

5. According to the OSHA Directorate of Technical Support and Emergency Management, the Occupational Safety and Health Act requires employers to comply with hazard-specific safety and health standards. In addition, employers must provide their employees with a workplace free from recognized hazards likely to cause death or

serious physical harm under Section 5(a)(1), the General Duty Clause of the Act. Employers can be cited for violating the General Duty Clause if there is a recognized hazard and they do not take steps to prevent or abate the hazard. However, failure to implement the OSHA anesthetic gas exposure guidelines is not, in itself, a violation of the General Duty Clause. Citations can only be based on standards, regulations, and the General Duty Clause. ²

General Techniques and Procedures for Decreasing Pollution

1. Anesthesia machines, ventilators, breathing systems, and waste-gas scavenging systems may contribute to environmental pollution with waste anesthetic gases.

Appropriate inspection for proper functioning and routine maintenance for such equipment should be standard operating procedures for veterinary facilities that use inhalant anesthetics.

2. The following outdated or dangerous procedures **should be discontinued for safety**, or, when absolutely necessary, be practiced with extreme caution and as explained where applicable

- Administering inhalant anesthetics by open drop (eg, periodically dripping liquid volatile anesthetic onto a gauze sponge) or insufflation (eg, delivery of a relatively high flow of anesthetic in oxygen into the trachea or pharynx through a catheter) techniques. If used, such techniques should be conducted in a chemical fume hood or at a distance from the source where operator exposure has been proven to be minimized. ³
- Turning on flow meters and vaporizers before the breathing system has been attached to the patient and the cuff of the endotracheal tube has been properly inflated.
- Allowing flow meters and vaporizers to remain on after the patient is disconnected from the breathing system.
- Using uncuffed endotracheal tubes that do not create a completely sealed airway or using cuffed tubes without inflating the cuff.
- Disconnecting a patient from a breathing system without eliminating as much of the residual gases as reasonably possible through the scavenging system. Systems should be flushed with oxygen (eg, empty the breathing bag through the pop-off valve periodically after the vaporizer has been turned off and employ an increased flow rate of oxygen [2-3 times maintenance flow] during recovery for circle breathing systems). The patient should remain attached - to the breathing system until extubation occurs.

- Spilling liquid anesthetic during the filling of vaporizers, especially during an anesthetic procedure. Ideally, properly functioning, agent-specific, keyed filler systems should be used, and at a minimum, a bottle adapter with a spout to prevent excessive spillage should be used. Routinely filling vaporizers at the end of the workday as personnel are leaving the hospital for the night should reduce exposure to waste gases.

3. The use of face masks and closed containers for delivery of inhalant anesthetics should be minimized. If employed, these techniques should be used in well ventilated rooms with non-recirculating ventilation systems or under a chemical fume hood.

4. Scavenging systems should be used with all inhalant anesthesia delivery systems to which they are adaptable. Unscavenged delivery systems should not be used except as described previously.

5. The lowest fresh-gas flow rates, consistent with the proper function of flow meters, vaporizers, and breathing systems and with patient safety, should be used (as opposed to very high fresh-gas flows). Although scavenging systems should function effectively for both high and low fresh-gas flows, low flows produce less waste gases. From the global perspective, low fresh-gas flow rates are consistent with protection of the earth's environment. ⁴

6. Routine filling of vaporizers should be performed with few people in the room and in a well-ventilated area. Filling vaporizers under a ceiling-mounted hood with an active evacuation system is ideal. Agent specific, keyed filler ports for vaporizers and corresponding keyed bottle adapters are available. Keyed bottle adapters with spouts should be employed to prevent excess spillage of anesthetic during the filling of vaporizers with screw-cap filler ports.

7. Employers should define and implement appropriate work practices to help reduce employee exposure. Training and educational programs covering appropriate work practices to minimize levels of anesthetic gases in the operating room should be conducted at least annually. Employers should emphasize the importance of implementing these practices and should ensure that employees are properly using the appropriate techniques on a regular basis. ⁵

Scavenging Systems

1. The use of scavenging devices with anesthesia delivery systems is the most effective way to decrease waste anesthetic gases; an efficient scavenging system is capable of reducing ambient concentrations of waste gases by up to 90%. **Anesthesia machines and breathing systems delivering halogenated hydrocarbon anesthetics and/or nitrous**

oxide should not be operated unless they are equipped with a functional scavenging system.

2. To be effective, a scavenging system must not leak and must control the concentration of trace anesthetics in ambient air. Waste gases should not be discharged into the outside air in an area where reentry through either the ventilation system or windows and doors is likely.

3. Although some variations exist, a scavenging system consists of a gas collecting device (eg, a scavenging pop-off or overflow valve), transfer tubing, an interface, additional transfer tubing, and a gas disposal system. Both passive and active scavenging systems are effective if set up and used properly.

4. Passive systems that simply vent gases to floor level and rely on inhalant anesthetic gases being heavier than air are unacceptable.

5. Non-recirculating room-ventilation systems, which provide 15 to 21 air changes/h, can be used for waste-gas disposal by routing transfer tubing to an exhaust grille.⁶ In addition, a non-recirculating room-ventilation system is an excellent adjunct to a scavenging system to reduce the concentration of waste gases that are inadvertently discharged into the room (eg, breathing system disconnect).

6. Recovery rooms can be polluted with significant amounts of waste gases (eg, gases exhaled by the patient after disconnection from the breathing system). Anesthesia machines with functional scavenging systems should be used as long as feasible in patients recovering from inhalant anesthesia. The breathing system should be flushed with oxygen and the reservoir bag expressed into the scavenging system before the endotracheal tube cuff is deflated or the breathing system is disconnected. Ideally, both large and small animal recovery rooms should have non-recirculating ventilation systems with a high rate of air exchange.

7. Facilities that utilize open-delivery systems that preclude the use of standard scavenging devices to control waste gases should allow use of such techniques only under a fume hood or similar system that allows rapid elimination of waste gases from the workplace.

8. Personal protective equipment should not be used as a substitute for engineering, work practice, and/or administrative controls in anesthetizing locations and recovery areas. Exposure to waste gases is not effectively reduced by gloves, goggles, and surgical masks. Negative-pressure, high-efficiency particulate air (HEPA) filters as used for infection control are also not appropriate to protect workers from waste gases. Air-supplied respirators with self-contained air source are ideal for eliminating exposure but are not a practical alternative.⁷

During clean-up and containment of large spills of liquid anesthetic agents, personal protective equipment should be used in conjunction with engineering, work practice, and/or administrative controls to provide for employee safety and health. Gloves, goggles, face shields, and chemical protective clothing (CPC) are recommended to ensure worker protection. Respirators, where needed, should be selected based on the anticipated contamination level. ⁷

9. Canisters containing activated charcoal can be used as waste-gas disposal systems in lieu of other types of scavenging systems, especially when portability is an issue. However, variation in effectiveness occurs with different brands of canisters and with changes in the rate of gas flow through the canister. ⁸ Activated charcoal is **not** effective for adsorption of nitrous oxide. Adsorption methods of scavenging are recommended only if other more reliable techniques are not available. Meticulous record keeping as to actual time of usage, or net gain in weight, is necessary to ensure effectiveness with this method.

Evaluation of Anesthetic Equipment

1. One of the most important sources of waste anesthetic gases is inhalant anesthetic equipment. Anesthesia machines and ventilators, breathing systems, and scavenging systems should be **checked for leaks prior to each use** and maintained to assure that they do not leak anesthetics into the atmosphere of the workplace.

2. The routine maintenance procedures for anesthetic equipment are usually explained in the operations manuals. Many anesthesia textbooks include guidelines for checkout of machines, breathing systems, ventilators, and scavenging systems. The specifics of these evaluations are too extensive for this report. **However, each piece of equipment involved in the delivery of inhalant anesthetics should be evaluated regularly to assure its function and integrity.**

3. Each veterinarian should become familiar with verification and maintenance procedures for the anesthesia equipment that he or she uses. It is his or her responsibility to learn such procedures, either by reading the appropriate operations manuals and textbooks or by consulting an expert.

4. The Occupational Safety and Health Administration (OSHA) recommends that checkout and maintenance procedures for anesthetic equipment be logged into a permanent record ⁵; Ideally a log of evaluation and maintenance procedures and leakage testing should be maintained for each anesthesia machine, ventilator, and vaporizer; maintenance and service logs are also recommended by the American Animal Hospital Association and the American Association for the Advancement of Laboratory Animal Science.

5. Procedures for verification of proper functioning are important prior to the use of anesthesia equipment, and personnel operating anesthesia equipment should be trained to complete these procedures and to recognize indications of equipment malfunction.

6. Procedures for verification of proper functioning of anesthesia equipment, depending on the equipment to be used, should include the following:

- *Status of the high-pressure system, including the oxygen supply (cylinder and central pipeline) and nitrous oxide supply* - The nitrous oxide supply should not leak when the cylinder valve is on and the nitrous oxide flowmeter is off.
- *Status of the low-pressure system (flowmeter function and evaluation for leaks in the low-pressure system)* - A negative-pressure leak test should be performed at the common gas outlet or the outlet of the vaporizer immediately upstream from the breathing system.
- *Status of the breathing system (including the condition of chemical absorbent for carbon dioxide, leak tests, and function of the pop-off or overflow valve and one-way valves)* - The status of the breathing system should be checked before using the system on each patient. An appropriate leak test for a circle system is to close the pop-off valve, occlude the Y-piece, pressurize the system to 30 cm of H₂O with all flow meters off, and ensure that the pressure does not decrease for at least 10 seconds. ⁹ Breathing systems different from the circle system can usually be checked for leaks by applying positive pressure to the system with all ports occluded, with similar guidelines as for circle systems. The quantity of leakage can be measured by determining the flow rate of oxygen necessary to maintain a constant pressure in the system, and the leak rate should be less than 300 mL/min at 30 cm of H₂O. ¹⁰
- *Status of the scavenging system* - The scavenging system should be properly attached at all connectors, and the appropriate vacuum should be assured for active systems. If charcoal canisters are employed for scavenging, they should be changed at appropriate intervals, according to the directions of the manufacturer.
- *Status of mechanical ventilators* - Ventilators should be connected properly to the anesthesia machine, and an absence of leaks should be assured. Ventilators with an inverted bellows should fill completely (rise to the top of the housing) during expiration, and ventilators with hanging bellows should not fall if the patient port is occluded at the end of inspiration.

Monitoring of the Effectiveness of Antipollution Techniques

1. Monitoring trace-gas concentrations in the workplace provides a quantitative assessment of the effectiveness of a waste-gas control program. Measuring the concentration of anesthetic in the breathing zone of the most heavily exposed workers is the usual procedure. Currently, no regulations require a veterinary hospital to measure waste-gas concentrations regularly. However, under the "general duty clause," an employer is required to provide training and a reasonably safe working environment for all employees. (See Introduction and General Techniques and Procedures)
2. Human workplace recommended exposure limits (REL) were issued in 1977 by the National Institute of Occupational Safety and Health (NIOSH); concentrations for halogenated inhaled anesthetics are not to exceed 2 ppm (1 hour ceiling) when used alone, or 0.5 ppm for halogenated anesthetics combined with 25 ppm N₂O (time-weighted average during use). The American Conference of Government Industrial Hygienists (ACGIH) assigned threshold limit value time-weighted averages (TLV-TWA) of 50 ppm for nitrous oxide, 50 ppm for halothane, and 75 ppm for enflurane for 8-hour time-weighted exposures. These concentrations were established because they were found to be attainable utilizing clinical scavenging techniques and there are no controlled studies proving exposure at these concentrations are safe. No NIOSH REL currently exist for the three most currently used anesthetics (isoflurane, desflurane, and sevoflurane) and, at present, OSHA has no permissible exposure limits regulating these specific agents. ¹¹
3. An accredited industrial hygiene laboratory is a source for assistance in establishing an air-monitoring program. Such laboratories are capable of sampling the air in the workplace and assaying such samples for inhalant anesthetics. Industrial hygienists can be found in the yellow pages of the telephone directory under "occupational safety."
4. An air-monitoring program is most appropriately started after anesthesia delivery systems have been equipped with scavenging systems and after other techniques for minimizing waste gas pollution are in place. An ideal approach would include frequent air monitoring, preferably at least semiannual evaluations.
5. Commercial companies offer personal monitoring systems (badges to be worn by individual workers) for the detection of nitrous oxide and halogenated inhalant anesthetics. Purchase of the monitoring badges may include prepaid laboratory analyses. Companies supplying these badges claim to accurately detect concentrations in the range of those recommended by NIOSH. Such monitoring has been recommended for veterinary practices.
6. Use of a portable infrared analyzer or commercial refrigerant leak detector has been proposed as a way for veterinary practices to monitor waste halogenated anesthetic gases within the workplace environment. ¹² Such a method might be economical if the monitor were shared by multiple practices.

7. After establishing procedures for control of anesthetic gases, the logical next step for veterinary clinics, hospitals, laboratories, and other institutions is the development of a consistent monitoring program for waste gases that is suitable, both qualitatively and economically, for the particular type of practice.

8. Concerning wildlife, zoo and outdoor research situations: When operating anesthetic equipment, the operator should obey all of the safety rules outlined in these articles. If activities are truly outdoors "in the open field" then anesthetic gas scavenging is problematic and may not be necessary. If individuals are in any type of enclosure (eg, tent, stall, vehicle, etc.) then operators should adhere to similar rules as proposed in order to protect personnel. This could include simply running a scavenge hose outdoors from the enclosure or using a charcoal absorbent canister as described in the Scavenging section.

Supplemental Reading

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From the American College of Veterinary Anesthesia and Analgesia (ACVAA).
Members of the 2013 ACVAA ad hoc Committee on Waste Anesthetic Gas Pollution
and Its Control were Drs. Sandra Allweiler, R. Bruce Heath, and Robert Meyer.

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