Anesthetic Waste Gas Management For Hollow Fiber Membrane Oxygenators

George A. Justison
William Beaumont Hospital,
Royal Oak, MI
PSICOR, Inc.
San Diego, CA

Abstract

Breathing of anesthetic waste gas has been shown to be harmful to operating room personnel. Improper use of scavenging systems with Hollow Fiber Membrane Oxygenators (HFMO) has been associated with arterial embolism. This study looked at the efficacy of a continuously vented active scavenge system. Environmental room air was tested for the presence of halogenated agents at 1, 3, and 6 foot radii from the HFMO. Presence of waste gas was measured using gas flows from 0.5 to 10.0 LPM and anesthetic gas concentrations from 0.5 to 5 percent of the total gas flow. Analysis shows that the continuously vented scavenge system maintains the environmental level below the recommended level of 2ppm.

Introduction

Personnel who work in the operating room arena are exposed to several sources of anesthetic waste gases. The primary source of the operating room pollutants is from the anesthesia machine and breathing circuit. Many studies have been done to isolate the source of these environmental waste products. Major contributors appear to be leaks from the high pressure gas systems on the anesthesia machine, supply lines to the ventilator, and the low pressure breathing circuit. The patient may also be a source for environmental pollution with anesthetic waste through improper fitting endotracheal cuffs and masks.

Little attention has been directed towards another source of operating room air contamination, the oxygenator exhaust gas. Many perfusion gas delivery circuits incorporate one or more types of halogenated agents to control the anesthetic level of the patient during the bypass procedure. Unless a proper scavenge system is incorporated into the circuit the oxygenator can be a potentially large contributor to environmental waste gas pollution.

Exposure of operating room personnel to anesthetic waste gas may have both short term and long term health risks. Short term risks include drowsiness, depression, irritability, nausea, headache, fatigue, loss of memory, and coordination. Potential long term risks have been identified as liver and kidney disease, cancer, and spontaneous abortion in pregnant OR staff.

The National Institute for Occupational Safety and Health (NIOSH) established guidelines for recommended time weighted exposure limits to anesthetic waste gases. Nitrous oxide exposure should be limited to a maximum of 25 parts per million over an eight hour period. Exposure to halogenated anesthetic agents (isoflurane, halothane, forane, etc.) should be contained to 2 parts per million (ppm) during an eight hour period.

Manufacturers of extra-corporeal oxygenation devices recommend the use of waste gas scavenging systems when using anesthetic agents but fail to make specific performance specifications for such systems. Some recommend the use of a wye connector in a vacuum line attached to oxygenator gas vent. This poses several safety hazards to the patient and staff. Should the line become occluded or bent between the wye connector and the gas exit port, overpressurization of the gas phase can occur forcing air to the blood phase resulting in arterial air embolization.

Blockage of the line distal to the wye connector will result in a loss of scavenging and pollution of the operating room environmental air with possibly hazardous agents.

This report evaluated the efficacy of a modified Bain Circuit to effectively remove all halogenated anesthetic agents from the gas exit port of a Hollow Fiber Membrane Oxygenator (HFMO).

Direct Communications to: George A. Justison, B.S., C.C.P., c/o PSICOR, Inc., 16818 Via del Campo Ct., San Diego, CA 92127.

Materials and Methods

A gas scavenge system was constructed from a Bain Circuit tube,[a] Hudson one-way 22mm valve,[b] and a Shiley endotracheal tube adapter.[c] The endotracheal tube adapter allows for the circuit to be adapted to a variety of gas exit port sizes on different HFMOs. The endotracheal adapter was attached to the Hudson one-way valve which prevents backward flow of gas into the HFMO gas vent should the scavenge system become pressurized. In addition, the Hudson valve incorporates an auxillary vent which helps prevent negative pressure build up in the circuit and provides an emergency gas vent port should the Bain tube become obstructed. Finally the Hudson valve is attached to a Bain Circuit tube. The Bain Circuit tube is a flexible 22mm breathing circuit with an inner tube construction designed for waste gas management.

In order to evaluate the gas removal ability of the modified Bain Circuit the gas delivery system used for the HFMO was simulated. A Maxima HFMO was attached via a ¼" × 72" polyvinyl chloride tubing with an integral gas line filter to an Ohio Medical forane vaporizer. The vaporizer received its gas source from a Sarns triple flowmeter attached to a wall oxygen source regulated at 50 psi. The endotracheal tube end of the modified Bain Circuit was attached to the gas exit port of the HFMO. The inner tube of the Bain Circuit was attached to a regulated wall vacuum source set at 120mmHg vacuum.

Analysis for leaks in the gas scavenge system was done by testing environmental room air at 1, 3, and 6 foot distances from the HFMO gas exit port for the presence of halogenated anesthetic agents. Analysis was performed by the constant aspiration of room air using an infrared spectrophotometer which reports the concentration of airborne agents based on the amount of infrared light absorption.

Analysis was done at each reference point from the HFMO under various combinations of total gas flow and percentage of forane. Total gas flow was set at 0.5, 1.0, 2.0, 4.0, 6.0, 8.0, and 10.0 liters per minute as indicated on the gas flowmeter. The concentration of vaporized forane was set at 0.5, 1.0, 2.0, 3.0, 4.0, and 5.0 percent increments of the total gas flow for each test. Table 1. Aspiration on the infrared spectrophotometer was set 250 ml per minute. Aspiration was continuous for 10 minutes at each reference point to allow for stabilization.

a Respiratory Care Inc., Arlington Height, IL 60004
b Hudson Corp.
c Shiley Inc., Irvine, CA 92714

Traffic was prevented in the room and all air conditioning was maintained at normal settings to model ideal environmental room exchange rates. All other sources of anesthetic gases were eliminated from the room.

Results

Table 1 lists the results from the gas spectrophotometer. Values listed are detected levels of environmental halogenated anesthetic agents in ppm at the respective total gas flow and percentage of vaporized forane present in the HFMO inspired gas. Inspection of the results shows that measured pollutant levels are well below the NIOSH recommended level of 2ppm. No halogenated agents were detected at the 6 foot reference point under any gas flow-concentration combination. Trace amounts of anesthetic pollutants were found when the gas concentration exceeded 3.0%. Only at the 10LPM gas flow and 2.0% concentration of halogenated agent was a measureable amount of leakage detected. Presence of waste gas in the environment decreased as the concentration of inspired gas decreased and the distance from the HFMO gas vent port increased.

Discussion

Scavenge systems designed for extra-corporeal use must meet several unique requirements in order to maintain maximum waste gas removal efficiency and provide unquestionable patient safety. The system must be capable of removing sufficient volumes of exhaust gas to prevent spillover through the secondary gas vents yet not generate excess negative pressure in the gas phase of the oxygenator. In addition the scavenge device must be designed to prevent inadvertent kinking which may result in over-pressurization of the gas compartment forcing gas across the membrane material.

The results of this study demonstrate that the modified Bain Circuit is able to significantly reduce the amount of environmental pollution generated by halogenated anesthetic waste gas. It was simple to construct from parts obtainable through most respiratory care or anesthesia departments.

It is important that all members of the operating room team coordinate their activities to improve the safety of the work environment for themselves and the patient. Table 2 lists five ways to reduce the risks of anesthetic waste gas exposure. Keep the scavenge device in close proximity to the heart lung machine and do not start any inhalation anesthetic until the scavenge system is in place and functioning. Do not

Table 1.

Environmental room air analysis results. Tot. GQ is total gas flow through the HFMO in liters/minute. Ref. Pt. is the distance for HFMO in feet.

TOT. GQ (LPM)	REF. PT.(ft)	GAS CONCENTRATION (%)					
		0.5	1.0	2.0	3.0	4.0	5.0
		DETECTED LEVELS IN PPM					
0.5	1	0.0	0.0	0.0	0.0	0.1	0.3
	3	0.0	0.0	0.0	0.0	0.0	0.1
	6	0.0	0.0	0.0	0.0	0.0	0.0
1.0	1	0.0	0.0	0.0	0.0	0.2	0.1
	3	0.0	0.0	0.0	0.0	0.0	0.0
	6	0.0	0.0	0.0	0.0	0.0	0.0
2.0	1	0.0	0.0	0.0	0.1	0.3	0.3
	3	0.0	0.0	0.0	0.0	0.0	0.1
	6	0.0	0.0	0.0	0.0	0.0	0.0
4.0	1	0.0	0.0	0.0	0.0	0.1	0.1
	3	0.0	0.0	0.0	0.0	0.0	0.0
	6	0.0	0.0	0.0	0.0	0.0	0.0
6.0	1	0.0	0.0	0.0	0.1	0.1	0.3
	3	0.0	0.0	0.0	0.0	0.0	0.0
	6	0.0	0.0	0.0	0.0	0.0	0.0
8.0	1	0.0	0.0	0.0	0.2	0.2	0.4
	3	0.0	0.0	0.0	0.0	0.1	0.2
	6	0.0	0.0	0.0	0.0	0.0	0.0
10.0	1	0.0	0.0	0.1	0.2	0.2	0.2
	3	0.0	0.0	0.0	0.0	0.0	0.1
	6	0.0	0.0	0.0	0.0	0.0	0.0

Table 2.

Methods to reduce operating room levels of anesthetic waste gases.

1. Do not start halogenated agents without a scavenge system in place and on.
2. Do not remove the scavenge system for several minutes after the agent has been discontinued.
3. Test for proper operation and leakage of the scavenge system on a quarterly basis.
4. Maintain a dedicated scavenge system in all cardiac operating rooms for perfusion use.
5. Maintain proper vacuum on the Bain Circuit to ensure the scavenge system flow exceeds the HFMO total gas flow.

remove the scavenge system for several minutes after the agent has been turned off. This will allow for any residual gas left in the gas circuit to be collected by the scavenge system. Test for the proper operation and presence of any leaks in the scavenge system on a quarterly basis. This test may be coordinated with the testing of the anesthesia machine and breathing circuit. Make sure that proper vacuum is maintained on the Bain Circuit to ensure that the scavenge system gas flow exceeds the total gas flow on the HFMO. Ideally the scavenge system flow to HFMO gas flow ratio should be 5:1. Finally inquire as to whether the operating room ventilation system meets all requirements for air exchange rates.

The use of a properly designed and maintained scavenge system can increase the safety to the patients undergoing cardiopulmonary bypass and reduce the hazards to operating room personnel from exposure to anesthetic pollutants.

References

1. Plummer JL, Sandison CH, Ilsley AH, Cousins MJ: Attitudes of anesthetics and nurses to anesthetic pollution. *Anaesthesia and Intensive Care,* 15 (4):411—20, 1987.
2. Brown D G, Wetterstroem N, Finch J: Anesthetic gas exposure. *AORN Journal,* 41: (3) 590—608, 1985.
3. Drinville-Shank G, Pregnancy in the OR *AORN Journal,* 45 (3) 746—7, 1987.
4. National Institute for Occupational Safety and Health, *Occupational Exposure to Waste Anesthetic Gases and Vapors: Criteria for a Recommended Standard,* 1976.
5. Springer JM, Murray BP, Romo R: Toxicity and management of waste anesthetic gases using the Sci-Med Oxygenator. *J Extra-Corpor Technol* (14) (3):368—370, 1982.

Questions from the Audience

Tom Utsey, Charleston, SC: Question: Could you briefly describe the Hudson valve and do you use a new one on each case? In your description could you at least give me your opinion as to whether it is possible for it to stick and become closed and pressurize gas inside the membrane?

Answer: A Hudson valve is a 22 mm rigid polyvinylchloride breathing circuit adaptor that has a low pressure flat valve inside it and is designed specifically for use in respiratory therapy equipment to activate one way flow. The valve requires a very low pressure to open. We chose that because of the one way valve and because of the availability of a secondary gas vent. And also because it was rigid and it allowed a rigid connection to the gas port which would prevent kinking. It is reusable, and the only time we change it is if some agent gets spilled down into it which may affect the flap function.

Sandra Pfefferkorn, Atlanta, GA: Question: I would just like to find out if you did any studies on the halogenated concentration in the operating room without using the scavenging system?

Answer: Yes. We did that but did not report the results here because of what it did. It put the spectrometer clear off scale and it is only capable of measuring anesthesic agents up to 10 parts per million. It also varies with what distance it was from the oxygenator and that may be due to the air exchange in the operating room.