

POLLUTION OF AMBIENT AIR BY VOLATILE ANESTHETICS: A COMPARISON OF 4 ANESTHETIC MANAGEMENT TECHNIQUES

Capt Joy C. Barberio, CRNA, MSN, USAF, NC
Lackland Air Force Base, Texas

Capt Jason D. Bolt, CRNA, MSN, USAF, NC
Andrews Air Force Base Medical Center, Maryland

Lt Col(ret) Paul N. Austin, CRNA, PhD, USAF, NC
Silver Spring, Maryland

Maj William J. Craig, CRNA, MSN, USAF, NC
Keesler Air Force Base, Mississippi

Long-term exposure to waste anesthetic gas (WAG) may lead to health problems. The purpose of this study was to compare WAG concentrations resulting from 4 combinations of fresh gas flow (FGF) and vaporizer settings during a simulated intravenous induction in which the anesthetic is deepened using a volatile anesthetic delivered via mask ventilation before intubation.

By using a lung model, WAG was sampled 3 times each using 4 combinations and 3 volatile anesthetics: 3% sevoflurane, 2% isoflurane, and 6% desflurane. The combinations were FGF off/vaporizer on, FGF on/vaporizer off, both on, and both off. WAG was measured using a MIRAN Ambient Air Analyzer placed at a level approximating the anesthetist's head. One-way analysis of variance with a Stu-

dent-Newman-Keuls post hoc test was used to compare the concentration of WAG among the combinations of FGF/vaporizer settings for each agent.

Regardless of the agent, only the FGF on/vaporizer on combination at 60 seconds resulted in a statistically greater WAG level ($P < .005$). The results support using 3 of the 4 combinations examined when mask ventilation with a volatile agent accompanies intravenous induction. Future studies should examine other methods of controlling WAG levels and use time-weighted averages to help address clinical significance.

Key words: Anesthesia, environmental monitoring, occupational exposure.

Despite decades of research, there is no definitive evidence that trace amounts of waste anesthetic gas (WAG) cause health problems.¹ However, there is no definitive evidence to the contrary. Government regulations mandate monitoring of WAG concentrations in the operating room (OR) and describe WAG limits.² Certainly this is based on the potential severity of health problems to healthcare workers and their children. Pollution of the OR with WAG is unavoidable when volatile anesthetics are used during the routine administration of an anesthetic. Potential sources of WAG include an incomplete face-mask seal, scavenging system malfunction, leakage of the gas mixture around an uncuffed endotracheal tube, and disconnection of the anesthetic circuit.³

An additional source of WAG is during an anesthetic induction of an adult in which anesthesia is induced with an intravenous agent and deepened with a volatile anesthetic agent before laryngoscopy and endotracheal intubation. In this scenario, the anesthetic agent is delivered via a face mask, and the face

mask is removed just before the laryngoscopy. Anesthesia providers commonly control the fresh gas flow (FGF) and/or adjust the vaporizer output to the patient to decrease WAG exposure during the period between removal of the face mask and reconnection of the breathing circuit to the endotracheal tube. The purpose of this study was to determine the combination of FGF/vaporizer adjustments that result in the least amount of WAG within the breathing zone of the anesthesia provider during a simulated adult intravenous induction, in which the anesthetic depth is deepened with a volatile agent before laryngoscopy and endotracheal intubation.

Materials and methods

After institutional review board approval, the study was conducted in 3 ORs. The ORs were of similar size, with two having an area of 368.33 square feet and the third an area of 365.49 square feet. The test setup consisted of a Narkomed 4 anesthesia machine (North American Draeger, Telford, Pa) with accompanying circle system with carbon dioxide absorber, standard

OR table, and a lung model. A coaxial breathing circuit (King F2, King Systems, Inc, Noblesville, Ind) was attached to the semiclosed circle system with a carbon dioxide absorber on the anesthesia machine. The lung model consisted of a 3-L anesthesia breathing reservoir bag (King Systems, Inc). The breathing zone was defined as a 2-foot vertical distance from the top right edge of the OR table where the anesthesia provider stands during induction and intubation of a patient. This area approximates the location of the head of the anesthesia provider.

The air exchange for each room was verified by the hospital facilities management department to be functioning properly with 15 exchanges per hour. Before each data collection period, the anesthesia machine, including the scavenging system, was prepared according to the manufacturer's recommendations.

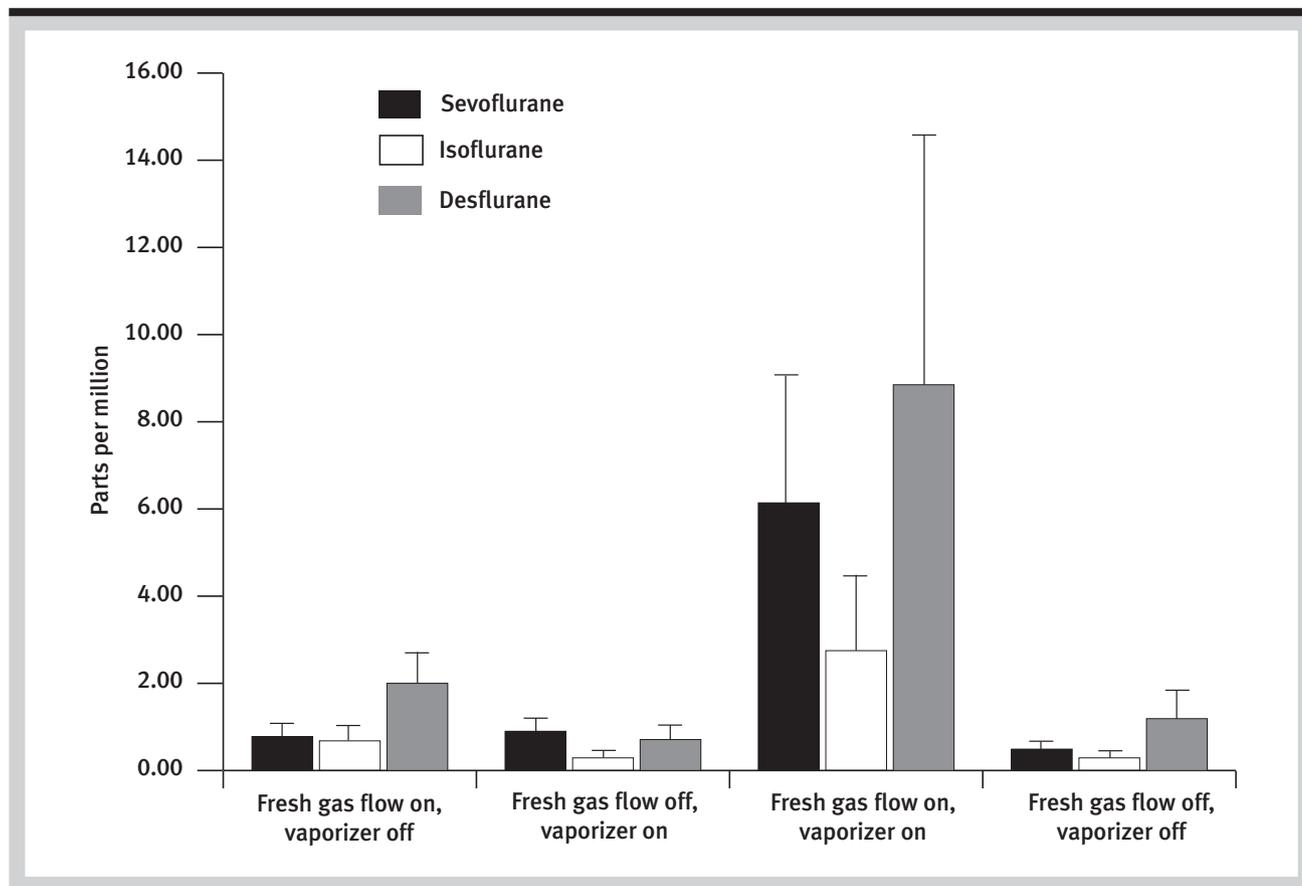
The MIRAN SapphleRe Ambient Air Analyzer (ThermoElectron Corp, Waltham, Mass) was used to measure the concentration of WAG. The MIRAN SapphleRe measures gases by infrared spectroscopy.⁴ This device and other infrared spectrophotometers have been used in prior investigations to measure WAG.^{5,6} The MIRAN SapphleRe reports the number of WAG

gas particles in the sampled air. Each gas has a different partial pressure and, thus, a different wavelength frequency that can be detected by the instrument.⁴ Once analyzed, the results are recorded as parts per million. The MIRAN SapphleRe was sent to the manufacturer, ThermoElectron Corp, for calibration before the start of the study to ensure accurate and precise data collection.

The WAG was sampled in each of the 3 ORs using 4 different anesthetic management techniques and 3 volatile anesthetics at predetermined concentrations: 2% sevoflurane, 1% isoflurane, and 6% desflurane. The 4 anesthetic management techniques were turning FGF off while leaving the vaporizer on, leaving FGF on while turning the vaporizer off, leaving both on, and turning both off.

We first performed a simulated intravenous induction consisting of an induction agent and a nondepolarizing muscle relaxant. While waiting for the effects of the intravenous agents during a timed 2-minute period, the lung model was ventilated with an oxygen flow rate of 10 L/min and a volatile agent at the predetermined concentration. This was done to simulate mask ventilation with a volatile agent used in con-

Figure 1. Mean \pm SD waste anesthetic gas concentrations in breathing zone at 30 seconds postintubation



junction with an intravenous induction. Tidal volume and respiratory rate were controlled at 500 mL and 12 to 14 breaths per minute, respectively.

After this 2-minute interval elapsed, we simulated intubating the patient-lung model. This consisted of a 30-second period in which the breathing bag was clamped and disconnected from the anesthesia circuit, and the circuit was placed on the tube tree at the top right hand side of the OR table. At the beginning of this 30-second intubation phase, the anesthetic management technique was implemented, ie, 1 of the 4 FGF/vaporizer combinations.

Immediately after the 30-second intubation period, the anesthesia circuit was reattached to the lung model, simulating the reattachment of the circuit to an endotracheal tube. Just before reattachment of the circuit to the lung model, the air in the breathing zone was measured for quantity of anesthetic agent by the MIRAN SapphleRe. The MIRAN SapphleRe also recorded WAG concentrations 1 minute after the circuit was reattached to the patient-lung model.

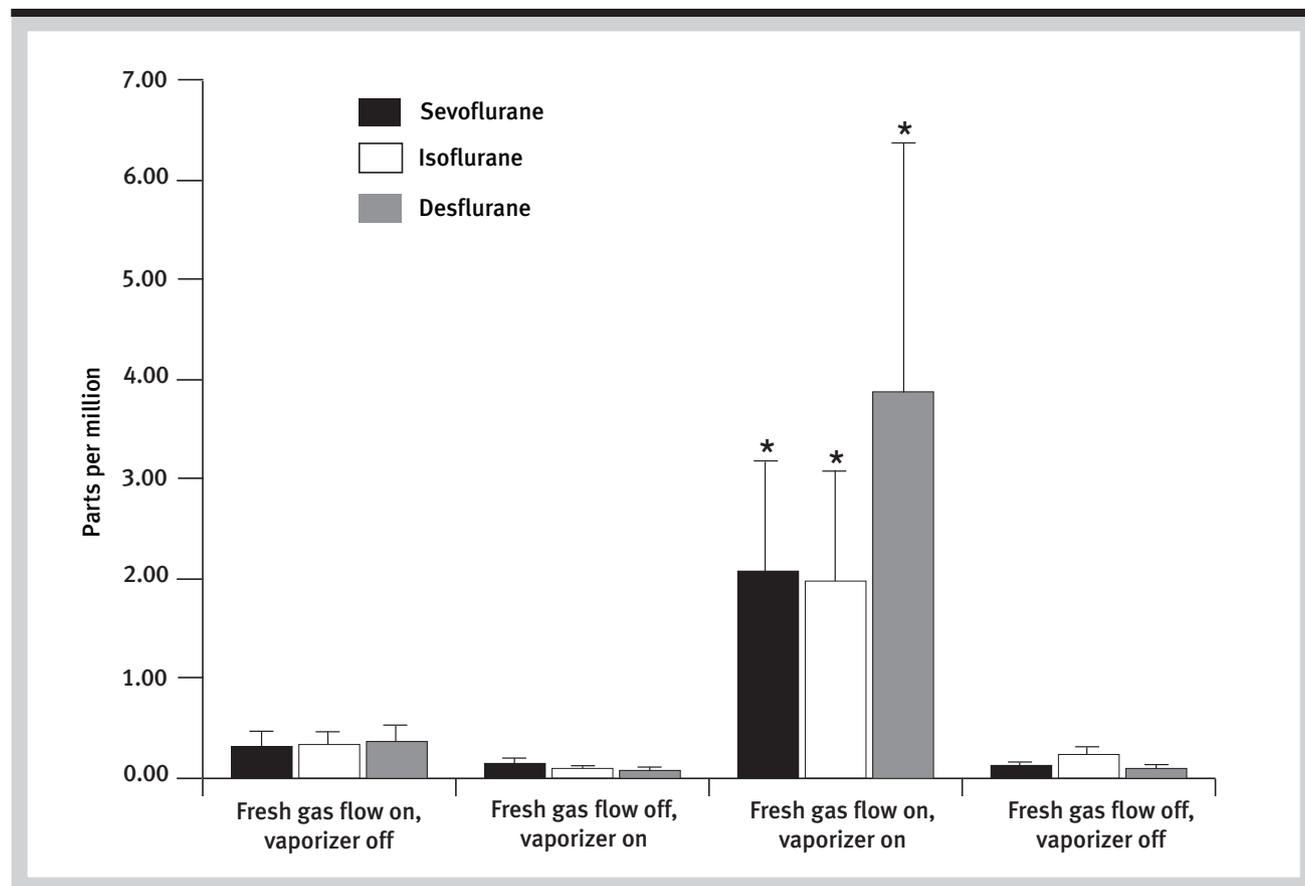
Statistical analysis was accomplished with the assistance of commercially available software package

(SPSS for Windows, Release 11.0, SPSS, Inc, Chicago, Ill). Measured WAG concentrations for each agent and combination of FGF/vaporizer setting obtained from each of the ORs were averaged and compared using 1-way analysis of variance with the Student-Newman-Keuls post hoc test. The 4 techniques were compared with each other for each of the volatile agents at the 30- and 60-second intervals.

Results

Mean concentrations of WAG at 30 and 60 seconds for the 4 management techniques and 3 concentrations are shown in Figures 1 and 2. Regardless of the volatile agent or anesthetic management technique, only the FGF on/vaporizer on technique yielded a statistically different WAG level ($P < .005$) at 60 seconds. These results were significantly higher than the other 3 anesthetic management techniques, which were not significantly different from each other. For each agent, the results at 60 seconds were not statistically different from those at 30 seconds, indicating a low likelihood of an interaction between technique and time.

Figure 2. Mean \pm SD waste anesthetic gas concentration in breathing zone at 60 seconds postintubation



* $P < .005$ compared with the other 3 techniques.

Discussion

The effect of WAG exposure to OR personnel is controversial and has been reviewed by many authors.^{1,7,8} Potential adverse health effects include hepatotoxic effects, adverse effects on DNA, teratogenicity, effects on neurobehavior, and miscarriage.⁷ Many of the epidemiological studies have varying degrees of methodological problems. However, as pointed out by one group, when the epidemiological studies are considered with animal and in vitro studies, governmental agencies and practitioners indicate procedures should be in place to limit the exposure of personnel to WAG.⁷

The findings of this study demonstrated that only leaving both the FGF and the vaporizer on yielded statistically different WAG concentrations at only the 60-second postintubation measurement. It was expected that this technique would yield higher WAG concentrations at the 30- and 60-second intervals. Interestingly, the other 3 techniques demonstrated reduced WAG concentrations but were not significantly different from each other at the 30- and 60-second intervals.

Turning the FGF off and leaving the vaporizer on likely limited the WAG concentration due to the lack of carrier gas flow to propel the anesthetic agent into the breathing zone. Turning the vaporizer off and leaving the FGF on had a similar effect on WAG by stopping the emission of anesthetic agent and/or diluting the anesthetic agent into the continued FGF. Turning the vaporizer and the FGF off had an effect on WAG similar to the maneuvers being performed separately. It must be noted that turning the FGF off during an anesthetic is not recommended and was included as part of the experimental protocol only for completeness.

Contamination of the OR by WAG has been examined and reviewed by other investigators.^{3,9} Studies typically were conducted during induction of anesthesia using a volatile agent, often in pediatric patients. Sources of contamination included leakage due to a poor face-mask seal, problems with the scavenging system, leakage around an uncuffed endotracheal tube, and leakage due to equipment malfunction.³ Previous studies did not examine the optimal FGF/vaporizer maneuver to limit WAG during the period between the end of mask ventilation and endotracheal intubation. Avoiding the use of a volatile anesthetic agent and/or nitrous oxide while ventilating the patient using a face mask reduces the time-weighted exposure of personnel to volatile agents.⁹ However, the controllability, efficacy, and convenience of the volatile agents makes these an attractive option to deepen the anesthetic level after an intravenous induction.

The present findings support the clinician not leav-

ing both the FGF and the vaporizer on during laryngoscopy and intubation. These findings support the previous recommendations of reducing occupational exposure to inhalation anesthetics.⁸ Burm⁸ also empirically recommended emptying the breathing bag and turning off the flow of nitrous oxide and the vaporizer.

This study was a preliminary investigation and used a relatively limited number of conditions. This study was conducted in a midsized hospital in the southeastern United States that had undergone various phases of restorations, including the air exchanger system. Of the 3 ORs used in the study, 2 were exactly the same size, and the third room was slightly smaller; this may have altered the measurements in the smaller room.

The use of a lung model cannot account for the uptake and distribution of volatile anesthetic that would occur in an actual patient scenario. Therefore, it does not account for the minimal amount of volatile agent that could leave the patient's airway and contribute to the amount of WAG in the atmosphere during the intubation period. Measurements in this study may be slightly higher than what would be found in a real-life scenario. Future studies should be conducted using an actual patient. In addition, time-weighted averages should be examined rather than periodic measurements.

Anesthesia providers should be cautious about WAG and limit exposure to these agents. The results of this study support providers using 1 of 3 techniques to limit WAG exposure. Anesthesia providers should consider adopting the technique that best fits in their practice.

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AUTHORS

Capt Joy Barberio, CRNA, MSN, USAF, NC, is a staff nurse anesthetist at Wright-Patterson Air Force Base Medical Center, Ohio. At the time this study was conducted, she was a student at Uniformed Services University of the Health Sciences (USUHS), Graduate School of Nursing, Nurse Anesthesia Program, Bethesda, Md.

Capt Jason Bolt, CRNA, MSN, USAF, NC, is a staff nurse anesthetist at Andrews Air Force Base, Md. At the time this study was conducted, he was a student at USUHS, Graduate School of Nursing, Nurse Anesthesia Program, Bethesda, Md.

Lt Col(ret) Paul Austin, CRNA, PhD, USAF, NC, is a staff nurse anesthetist at the Surgery Center of Maryland, Silver Spring, Md. At the time this study was conducted, he was the program director at USUHS, Graduate School of Nursing, Nurse Anesthesia Program, Bethesda, Md.

Maj William J. Craig, CRNA, MSN, USAF, NC, is an instructor at the US Army Graduate Program of Anesthesia Nursing, Fort Sam Houston, Texas. At the time this study was conducted, he was clinical site director, Keesler Air Force Base Medical Center, Miss, and an adjunct assistant professor, USUHS Nurse Anesthesia Program, Bethesda, Md. Email: william.craig@amedd.army.mil

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