



Waste Anesthetic Gase: A Forgotten Problems

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ABSTRACT

Waste anesthetic gas (WAG) is a small amount of inhaled anesthetic gas that comes out of the patient's anesthesia breathing circuit into the environment air while the patient is under anesthesia. According to American Occupation Safety and Health Administration (OSHA) more than 200.000 healthcare workers especially anaesthesiologist, surgery nurse, obstetrician and surgeons are at risk of developing work-related disease due to chronic exposure to WAG. Exposure to WAG in short time associated with multiple problems such as headaches, irritability, fatigue, nausea, drowsiness, decrease work efficiency and difficulty with judgment and coordination. While chronic exposure of WAG is associated with genotoxicity, mutagenicity, oxidative stress, fatigue, headache, irritability, nausea, nephrotoxic, neurotoxic, hepatotoxic, immunosuppressive and reproductive toxicological effect. Waste anesthetic gases are known as environmental pollutants and will be released from the OR to the outside environment then the substance will reach the atmosphere damaging ozone layer. Exposure to trace WAG in the perioperative environment cannot be eliminated completely, but it can be controlled. Controlling WAG can be achieved by using scavenging system, proper ventilation, airway management, ideal anesthetic choice, maintaining anesthesia machine and equipment, hospital regulation and routine healthcare workers health status examination.

Keywords: inhalation anesthetics, environmental pollutants, anesthesia, stratospheric ozone, airway management.

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Introduction

Anesthetic gases and vapours that leak into the surrounding during anesthesia procedures are considered waste anesthetic gases (WAG) ¹. Waste anesthetic gases are small amounts of anesthetic inhalation product that are typically found in operating room (OR) and post anesthesia care units (PACU) ambient air. Anesthetic that contain halogens such as halothane, isoflurane, sevoflurane, desflurane and N₂O are the most common inhaled anesthetic agents and potentially become as WAG².

According to American Occupation Safety and Health Administration (OSHA) more than 200.000 healthcare workers are at risk of developing work-related disease due to chronic exposure to WAG^{1,2}. Every healthcare workers (anaesthetists, nurse, obstetrician and surgeons) who works in and around operating room is continuously exposed to WAG. In operating room there are multiple potential sources of WAG into the atmosphere including exhaust valve, ventilator circuit connections, defects in plastic insufflation balloons or ventilator connectors ³. There will be some anesthetic gases leaks between the patient and the anesthesia circuit. Patients do not absorb all the inhaled anesthetic agents into lungs and some will return to anesthesia machine. National Institute for Occupational Safety and Health (NIOSH) recommend WAG concentration >2ppm over a sampling period do not exceed 1-hour exposure time. Recent studies suggest that potential postanesthesia care units (PACU) nurse may have even higher air concentration of WAG above NIOSH guideline. In postanesthesia, trace amounts of anesthetic waste agents will released from patient breath³⁻⁵.

In 1977 NIOSH limits the use of halothane and nitrous oxide as anesthetic agents³. The second edition of the Ministry of Health Formulary drug lists (2014) stated that isoflurane and sevoflurane are the most widely used inhaled anesthetics agents now ⁶. Even newer anesthetic agent such as isoflurane also have potential health effects include headache, fatigue, transient blurring of vision, nausea, malignant hyperthermia in some individual, hypotension, hepatotoxicity and slight increase in risk for miscarriages at acute doses. Sevoflurane exposure shows significantly higher blood fluoride level which induce reduction in hemoglobin, red blood cell count and platelet. This agent also induced hepatotoxicity in healthcare workers while there were no hepatotoxic consequences in surgical patients. Till now, studies do not show that chronic exposure lead to carcinogenic ^{6,7}. Chronic exposure of WAG is associated with reproductive problems, fatigue, headache, irritability and nausea⁶.

Exposure to trace WAG in the perioperative environment cannot be eliminated completely, but it can be controlled. This is a public health problem, so knowledge of risks, the



application of healthcare workers behavior and regulation of exposure to this WAG is important to reduce WAG level in the operating room to minimum level that is safe for healthcare workers². This review article aimed to review the impact of WAG on healthcare workers and the work environment as well as to review about genotoxicity, mutagenicity, oxidative stress and WAG control in operating room.

Waste Anesthetic Gases Definition

Waste anesthetic gas is a small amount of inhaled anesthetic gas that comes out of the patient's anesthesia breathing circuit into the environment air while the patient is under anesthesia. This gas can be inhaled by patients who are recovering from post anesthesia. These WAG include N₂O and halogen anesthetic such as halothane, enflurane, isoflurane, desflurane, sevoflurane, and methoxyflurane. Halogen anesthetic gases are often used in combination with N₂O. N₂O and some halogen anesthetics can present a hazard for exposed healthcare workers⁸. Inhaled anesthetic agents widely used in operating room and in PACU or in recovery rooms, so that healthcare workers who work in these places are at risk of exposure to WAG. According to NIOSH, healthcare workers who are at risk of exposure to WAG include anesthesiologist, surgeons, dentist, nurse and other technician in operating room or recovery room⁸.

The leakage of anesthetic gases into the ambient air occurs when the anesthetic gas exits the breathing circuit into the patient's airway. The use of facemask in pediatric patients, laryngeal mask or endotracheal tube (ETT) without cuff can also significantly increase the concentration of anesthetic gas leakage in the operating room. The anesthesiologist respiratory working area is the most important source of this leak.¹ There are several main causes of WAG such as the anesthetic technique, anesthesia workstations, and operating room scavenging systems².

There are several anesthetic techniques that can increase WAG production, such as (1) induction with inhalation anesthetic technique especially in pediatric patients, (2) failure to turn off the flowmeter control valve and vaporizer when the operation is complete, (3) leakage of anesthetic agents when filling the vaporizer, (4) flushing at the end of surgical procedure to speed up recovery, (5) problems with the placement of the face masks (material or size is not suitable) (6) gas leakage after inadequate ETT or LMA cuff inflation, (7) use of intermediate fresh gas flow (FGF) 2-4 lpm, especially with high flow (>4 lpm), (8) use of sidestream type capnography in the absence of backflow of gas to anesthesia machine, (9) use of Mapleson respiratory system, especially in pediatric anesthesia².



The cause of leaks due to the anesthesia workstation is the results of leaks in several components of the anesthesia workstation. Possible leaks can come from the valve and breathing circuit connection or as a result of damage to the reservoir bag².

Scavenging system play a major role in eliminating WAG in the operating room and can reduce both anesthetic pollution and the risk of occupational exposure. There are two type of scavenging system: global (central suction draws air from OR through negative pressure and venting all the air with waste gases outside the room without air recirculation) or partial (central suction that draws air from OR through negative pressure and partially venting the air with anesthetic gas to the outside with air recirculation). The use of a proper scavenging system can make the average results gas concentration in both isoflurane and sevoflurane below 2 ppm. Occupational exposure to WAG in the operating room without a scavenging system is associated with adverse health effects, such as headache, irritability, neurobehavioral changes, and DNA damage^{2,9}.

Waste Anesthetic Gases Health Implication

Waste anesthetic gases have short-term and long-term health implication. However, the side-effect of WAG on healthcare workers who exposed for a long time are still controversial^{4,10}. Exposure to WAG in short time associated with multiple problems such as headaches, irritability, fatigue, nausea, drowsiness, decrease work efficiency and difficulty with judgment and coordination which disappeared after the person left the workplace^{5,10}. Even newer anesthetic agent such as isoflurane also have potential health effects include headache, fatigue, transient blurring of vision, nausea, malignant hyperthermia in some individual, hypotension, hepatotoxicity and slight increase in risk for miscarriages at acute doses. Sevoflurane exposure shows significantly higher blood fluoride level which induce reduction in hemoglobin, red blood cell count and platelet. This agent also induced hepatotoxicity in healthcare workers while there were no hepatotoxic consequences in surgical patients^{6,7}.

Chronic long-term effect of WAG correlate to the concentration of gas, measured in ppm and udartion of exposure⁴. Till now, studies do not show that chronic exposure lead to carcinogenic^{6,7}. Chronic exposure of WAG is associated with reproductive problems, fatigue, headache, irritability, nausea, nephrotoxic, neurotoxic, hepatotoxic, immunosuppressive and reproductive toxicological effect^{6,11}.

There were several animal studies shown that exposure of high levels of WAG potentially induce cellular, mutagenic, carcinogenic and teratogenic effects. However, because



concentration of agent and duration of exposure are significantly different between animal and human, animal studies could not be used to predict the effect of human exposure ⁴.

Neuropsychological symptoms are often subjective, while biological parameters may be more measurable. Recent studies on human subject found that there were genotoxicity damage, DNA damage and mutation, and increased oxidative stress because of WAG exposure¹⁰⁻¹³.

The mechanism of genotoxicity and mutagenicity of inhaled anesthetic are not fully understood. There were several theories where oxidative and anesthetic drugs metabolism is capable of generating reactive oxygen species (ROS) and direct damage to genome at cell cycle, nucleic acid, lipid and protein. Nitrite oxide oxidizes the cobalt ion in vitamin B12 lead to inhibition of methionine synthetase with reduced production of methionine, tetrahydrofolate, thymidine and nucleic acid. This change could lead to megaloblastic anemia, agranulocytosis, spinal cord subacute combined degeneration and neurobehavioral disorder in chronic exposure of N₂O. Another mechanism is that WAG could act similarly as radiomimetic drugs, such as S-independent compound, inducing damage in all cell cycle phases ^{2,12}. Systematic review by Yilmaz et al (2016) found chromosomal aberrations, sister chromatid exchanges, micronuclei and comet assay were the most frequently used genotoxicity end-points. Exposure of WAG has been associated with significant increase in genotoxic damage ¹¹.

Oxidative stress is an imbalance of ROS and antioxidant production. Oxidative stress could induce damage to macromolecules, including nucleic acids, lipids, and protein resulting in cellular damage, as well as various disease ². Studies shown that medical resident from Anesthesiology and Surgery areas exposed continuously to WAG without proper scavenging system have increased DNA damage and oxidative stress¹².

Waste Anesthetic Gases Environment Implication

Waste anesthetic gases are known as environmental pollutants and will be released from the OR to the outside environment then the substance will reach the atmosphere ¹⁴. Environmental damage due to anesthetic gases depends on the molecular weight, proportion of halogen atoms and their half-life in the atmosphere. The anesthetic gases half-life includes N₂O is 114 years, desflurane is 10 years, halothane is 7 years, sevoflurane is 5 years and isoflurane is 3 years. All of the inhalation anesthetic used contain compounds that resemble chlorofluorocarbons and therefore have a damaging effect on the ozone layer. In addition to being a type of gas that damage the ozone layer, N₂O captures thermal radiation emitted from



the earth's surface and contributes to the global warming phenomenon known as the greenhouse effect ².

Anesthetic agents are part of the greenhouse gas. Waste anesthetic gases is routinely removed from the OR into the atmosphere through scavenging system^{15,16}. Emission from infrared radiation through atmospheric windows into space are an important mechanism because this will affect Earth's temperature. Anesthetic gases have an infrared absorption band that overlaps with outward radiation, they can block the flow of infrared radiation into space, and thus act as greenhouse gases². The global warming potential (GWP) of halogenated anesthetics is 2000 times greater than carbon dioxide¹⁶.

Table 1. Radiative properties, Atmospheric Lifetime and GWP for N₂O and other halogenated anesthetic gases¹⁵

Compound	Atmospheric lifetime (year)	Radiative efficiency (W m ⁻² ppb ⁻¹)	GWP			ozone depletion potential
			20-y time horizon	100-y time horizon	500-y time horizon	
N ₂ O	114	0.00303	289	298	153	0.017
Halothane	1.0	0.165	190	50	20	0.4
Enflurane	4.3	0.447	2370	680	210	0.01
Isoflurane	3.2	0.453	1800	510	160	0.01
Desflurane	14	0.469	6810	2540	130	0
Sevoflurane	1.1	0.351	440	130	40	0

GWP = global warming potential

Although isoflurane, sevoflurane and desflurane all have a higher GWP factor than N₂O, N₂O contributes the most to increased climate impact (99,97%) because the volume of N₂O consumption far exceeds other anesthetic gases².

Waste Anesthetic Gases Control

National Institute for Occupational Safety and Health (NIOSH) in 1977 recommend allowable WAG concentration 2ppm for halogenated anesthetic gases and 25 ppm time weighted average (TWA) for N₂O in scavenging system. Operating room without scavenging system is more widely applied in hospitals and have concentration of isoflurane, sevoflurane and desflurane above 5 ppm and for N₂O more than 170 ppm TWA (above NIOSH recommendation)²



Table 2. Allowable anesthetic gases concentration in OR (in ppm)¹⁷

	Sevoflurane	Isoflurane	Enflurane	Desflurane	Halothane	N ₂ O
Austria					5	
Denmark	-	-	2	-	5	100
France	-	-	-	-	2	-
Germany	-	-	20	-	5	100
England	-	50	50	-	10	100
Italy	-	-	-	-	-	100
Norway	-	2	2	-	5	100
Sweden	-	10	10	-	5	100
Switzerland	-	10	10	-	5	100
United States	2	2	2	2	2	25

Despite the controversy regarding the effects of WAG exposure on human health, it is important to make effort to reduce the concentration of WAG in OR and other contaminated area. Here are some control measure to minimize WAG in OR:

1. Use of air-conditioning and scavenging systems. Contamination of WAG to the surrounding can be caused by the presence of a recirculation system that is only capable of minimal air exchange and is a closed ventilation system. Place the exhaust in an area where WAG will not be reintroduced into intake air for the facility. Install a ventilation system that circulates and replenishes the air in OR (at least 15 air changes per hour, with a minimum of 3 air changes of fresh air per hour) (CDC) In OR with normal ventilation systems, N₂O levels can exceed the minimum threshold according to the specified standards. The use of ventilation with air conditioning and scavenging system can reduce the WAG concentration by almost 20 times lower than normal ventilation¹⁰. There is another type of scavenging system that is thought to reduce the concentration of anesthetic gas residues significantly. The scavenging system is an anesthetic scavenging hood (ASH). This is a scavenging system with one gas pipe outlet. These objects are located side by side along the suction pipe which extends to the inside and protrudes from the inside of the hood. The outer side of the tubing of the protruding part will meet the part of the suction hose which can be connected to the vacuum source. The ASH also provides a hole that allows the ETT to come out of the hood from the ASH. Using vacuum power with ASH provided very significant results in reducing anesthetic gas concentration in the ambient air in OR. Using ASH can reduce high WAG concentrations (2000 ppm) into the recommended minimum WAG exposure threshold¹⁸.

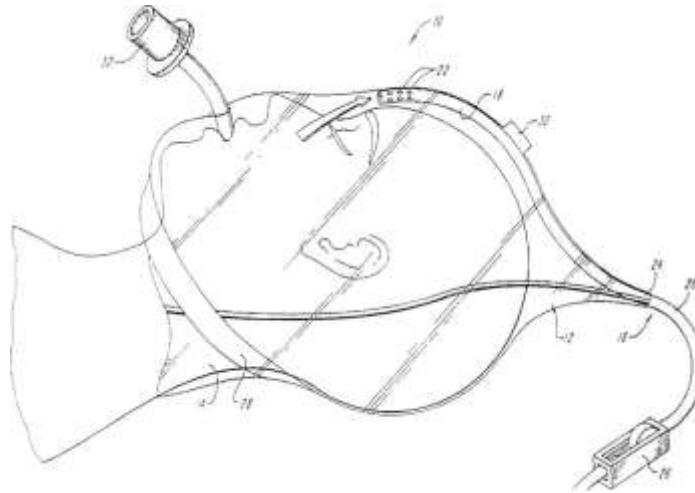


Figure 1. Schematic illustration of ASH¹⁸

2. Anesthetic induction method. The method of induction by inhalation anesthesia increased the WAG concentration 50 times higher than intravenous induction. Residual anesthetic gas levels in the environment were significantly reduced by the intravenous induction technique compared to inhalation technique¹⁹. Even though using a breathing bag or system circle circuit, the WAG concentration is still high and exceeds the recommended threshold standard. The double-mask system is a new mode of inhalation induction. The inner layer of this double-mask is a soft cover for the gas transmission line and the outer layer mainly serves to extract the exhaled gas. This double-mask is not only a tool for channeling the anesthetic gas to the patient's respiratory tract, but also can clean the WAG around the patient's head¹⁰. Use the lowest anesthetic gas flow rates possible. Avoid very high anesthetic gas flow rates to prevent leaks. Turn the gas off before turning off the breathing system⁸.
3. Airway management. In airway management using the cuffed oropharyngeal airway (COPA), laryngeal mask airway (LMA), or Cobra, the WAG concentration around the patient increase beyond the recommended exposure threshold, even 20 fold higher in the anesthetist's breathing zone¹⁰. Start the gas flow after the laryngeal mask or ETT is installed⁸.
4. Maintain anesthesia machines, breathing circuits and scavenging system to minimize leaks of anesthetic gases into the OR. Inspect the anesthetic delivery system before using and look for irregularities or breaks. Fill vaporizers before or after the anesthetic procedure¹⁰.
5. Healthcare workers training in hazard awareness, prevention and control of exposures to WAG¹⁰.



6. Keep good records of all collected air sample results and healthcare workers medical records for at least 30 years. Routine check for healthcare workers and their families health status, including occupational histories, pregnancy status and baseline liver and kidney function⁸.

Recent studies in PACU demonstrated that to control WAG exposure, the healthcare workres should use appropriate mask size selection and adjustment, minimal talking, mouth breathing by the patient and proper scavenging system⁵. Installing a ventilation system that circulates and replenishes the air in recovery room (at least 6 air changes per hour, with a minimum 2 air changes of fresh air per hour) to prevent exposure to WAG exhaled by patients⁸. To reduce WAG and prevent climate change, there are several mitigation procedure for inhaled anesthetic gases such as keep fresh gas flow low (ASA recommends FGF of 1 l/min for maintenance anesthesia), avoid desflurane and nitrous oxide except when specifically indicated for specialized clinical condition, reconsider the use of nitrous oxide for labor analgesia, use IV and regional anesthesia when feasible, turn off FGF during intubation, proper scavenging system^{14,15}.

Conclusion

Waste anesthetic gases have short-term and long-term problems for healthcare workers especially in operating room, PACU and recovery room. This problem cannot eliminated completely. Controlling WAG can be achieve by using scavenging system, proper ventilation, airway management, ideal anesthetic choice, maintaining anesthesia machine and equipment, hospital regulation and routine healthcare workers health status examination.

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