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## Research Article

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## Waste Anesthetic Gases and the Incidence of Miscarriage

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### Abstract

**Background:** Waste anesthetic gases are vapors and anesthetic gases that leak into the surrounding environment during a medical procedure. Waste anesthetic gases pose a potential risk for pregnant healthcare workers in hospitals, dental practices, and veterinary clinics.

**Aim:** This article synthesizes the peer-reviewed literature about the effect of occupational exposure to waste anesthetic gases.

**Design:** This evidence-based analysis report is a critical evaluation of the question “Does exposure to waste anesthetic gases increase the incidence of miscarriage in female healthcare providers?”

**Method:** Seminal and recent literature is reviewed related to spontaneous abortion and occupational exposure to waste anesthetic gases.

**Conclusion:** Research indicates pregnant healthcare workers are at an increased risk for spontaneous abortion when exposed to waste anesthetic gases. To minimize exposure, it is recommended to use a well-functioning scavenging and filtering system.

**Keywords:** Inhaled anesthetics; Occupational hazards; Pregnant; Waste anesthetic gases

### Introduction

In the United States, approximately 200,000 healthcare professionals are exposed to waste anesthetic gases annually according to the Occupational Safety and Healthcare Administration. Waste anesthetic gases are small amounts of nitrous oxide and halogenated anesthetics such as sevoflurane, that leak into the environment during the medical procedure. As anesthesia has progressed, safety measures have been taken to reduce the amount of exposure to anesthetic gases. These safety measures include improved scavenging systems, air filtration and ventilation, and leak alarms on the ventilator. The purpose of this analysis is to determine if exposure to waste anesthetic gases may cause an increased incidence of miscarriages in female healthcare workers. The potential risk for spontaneous abortion related to occupational exposure to anesthetic gases is not limited to anesthesia providers, nurses, or surgical assistants. The risk also extends to veterinarians, veterinarian assistants, dentists, dental assistants, midwives, patients, and radiology technologists who are exposed to anesthetic gases. Conducting an evidence-based review may raise awareness in healthcare professionals concerning anesthetic techniques that may cause an increase or decrease in the risk of occupational exposure.

### Discussion

The National Library of Medicine database PubMed and the Cumulative Index to Nursing and Allied Health Literature (CINAHL) were used to search for articles. The keywords used were miscarriages related to anesthetic gases, anesthesia occupational hazards, pregnant, and female. Evidence-based, peer-reviewed research articles were found using the databases. Articles that were not peer-reviewed were excluded. Reviewed articles consist of controlled trials, meta-analyses, and retrospective studies. Article selection was based on level of evidence and implication on clinical practice. We posed the PICO question “Does exposure to waste anesthetic gases increase the incidence of miscarriage in female healthcare providers?” Seminal and recent literature reviewed related to spontaneous abortion and occupational exposure to anesthetic gases are listed in (Table 1).

Articles	Description	Level of Evidence	Population	Results
[1]	Occupational Reproductive Hazards for Female Surgeons in the Operating Room	Level 4 Cohort study	1021 United States female surgeons	Reproductive hazards such as infertility are associated with anesthetic waste gases as well as other factors in the OR.
[2]	Analyzed 19 different studies regarding the association of waste anesthetic gases and risk of spontaneous abortion.	Level 1 Meta-analysis	Women occupationally exposed to anesthetic gases	The association of waste anesthetic gases and risk of spontaneous abortion. The author found an overall relative of risk of miscarriages related to exposure to anesthetic gases was 1.48, 95% confidence 1.4 to 1.58
[3]	Examine fetal injury and abortion associated with occupational exposure to inhaled anesthetics.	Level 4 Cohort study	Does not list a specific number or population. Does compare rodents to human fetuses	Argues the use of volatile anesthetic gases poses very low risk for teratogenicity or miscarriage
[4]	Nitrous oxide in waste anesthetic gases with different fresh gas flow.	Level 6 Case-control study	Five patients and excluded anyone with cardiopulmonary disease, having a laparoscopic procedure, and pregnant.	The N <sub>2</sub> O percentage in the anesthesia waste gases with a FGF of 600, 1200 and 1800 mL was 3.4 ± 0.54, 8.2 ± 0.83 and 14.0 ± 0.70, respectively. The researchers determined that fresh gas flow of less than 600 ml/min will need a scavenging system to limit the exposure of nitrous oxide into the air.
[5]	Occupational exposures among nurses and risk of spontaneous abortion.	Level 4 Cohort study	8, 461 nurses. After the exclusion criteria only 7,482 women were left in the analysis	Investigators found that 1.07 odds ratio for a confidence interval 0.81-1.40 produced spontaneous abortions during the first trimester. Investigators concluded that anesthetic gases did not have a significant association with spontaneous abortion especially when compared with other occupational hazards like radiation
[6]	Occupational hazards, DNA damage, and oxidative stress on exposure to waste anesthetic gases.	Critically appraised individual articles (article synopses)	Review of research: Effect of waste anesthetic gases that impact healthcare professionals' health	Concluded that halogenated anesthetics effect the genome at any stage of the cell cycle and cause damage
[7]	Evaluation and control of waste anesthetic gases in the post-anesthesia care unit.	Level 3 Control Trial	19 patients and PACU nurse The study excluded patients with a body mass index great than 40 or any patient with pulmonary disease	The researchers concluded that there was a significant reduction in the amount of waste anesthetic gases the nurses were exposed to at least 3 feet away from the patient's breathing zone.
[8]	Occupational exposure to trace concentrations of waste anesthetic gases.	Level 4 Cohort Study	No specific population is listed other than healthcare workers. Some studies compared rodents and humans	Teratogenic effects leading to fetal resorption and fetal development abnormalities increase in spontaneous abortions in operating room personnel through surveys Areas where a safe level of exposure was maintained did not show an increase in spontaneous abortion.
[9]	This study examined occupational hazards with preterm delivery in female veterinarians.	Level 4 Cohort study	1355 pregnancies, 744 in final analysis, characteristics: Female, veterinarian, pregnant	54/744 singleton live births were classified as preterm 11/744 were classified as very preterm Highest risk were in women who graduated from Sydney University
[10]	This study was a review of research synthesizing evidence to answer the question: Is occupational exposure to anesthetic gases a concern for pregnant women?	Level 1 Critically appraised individual articles (article synopses)	854 anesthetists and 25% are women with 46% being of childbearing age...2,745 veterinarians with 45% are women	Authors find evidence from critically appraised research that pregnant healthcare workers in direct contact with patients under general anesthesia need to minimize their exposure to waste anesthetic gas to reduce the risk of spontaneous abortion. Recommendations include but are not limited to: Using scavenging system Test anesthesia machine for gas leaks

**Table 1:** Seminal and Recent Literature Related to Spontaneous Abortion and Occupational Exposure to Anesthetic Gases.

### Waste Anesthetics Increase Risk of Spontaneous Abortions

To understand the development in the field, relevant seminal work performed by Boivin [2] is presented first. Boivin conducted a meta-analysis comparing results from 19 different studies regarding the association of waste anesthetic gases and risk of spontaneous abortion [2]. The researcher used a scoring system ('0' no risk, '1' moderate risk, '2' high risk) and determined that the overall mean risk of miscarriages related to exposure to anesthetic gases was 1.48 (95% confidence interval 1.4 to 1.58). Boivin concluded that there is an increased risk in spontaneous abortions with unscavenged systems. Another historically relevant study was conducted by Shirangi, et al. [9]. The researchers conducted a cohort study investigating occupational hazards related to reproductive hazards for female veterinarians. Hazard variables included radiation, anesthetic gases, pesticides, and long working hours. The reproductive risk focus was preterm labor and the risk of spontaneous abortions. The researchers defined preterm labor as birth before 37 weeks of gestation. The researchers evaluated 744 pregnancies for occupational exposures during gestational weeks 22 through 37. Relative risks and 95% confidence interval 7.3% of pregnancies ended in preterm birth. 1.5% ended in preterm birth less than 32 weeks' gestation compared to the 5.7% of the general population of Australia. Using the Kaplan-Meier cumulative risk analyzer it was determined that veterinarians that worked greater than forty-five hours per week and were exposed to waste anesthetic gases without a scavenging system had a 9% cumulative risk for preterm labor. The researchers also found that preterm delivery had a 2.5-fold increase in veterinarians that were exposed to gases more than 1 hour per week.

An article written by Shuhaiber and Koren [10], explored studies investigating increased risk of major congenital malformations or increased risk of spontaneous abortion related to occupational hazards in pregnant women. The researchers identified that there were 854 anesthetists practicing in Ontario, Canada. Of those roughly 213 were women; 46% of the women were in childbearing age. The researchers also mentioned that 45% of 2,745 practicing veterinarians or women. The results presented in the article from the studies included occupational exposure to waste anesthetics has an increase relative risk of 1.4 with a confidence interval of 1.4 to 1.5 in relation to spontaneous abortion. Spontaneous abortion among dental assistance exposed to nitrous oxide was increased, although the P value was not reported. It noted that another study reported that dental assistants exposed to nitrous oxide for more than three hours had an increased risk of spontaneous abortions. Another study regarding midwives that use nitrous oxide in 50 % or more of their deliveries for analgesia, had no increase in risk of spontaneous abortions [10]. The authors concluded that the risk of spontaneous abortion related to the exposure of nitrous oxide is complicated and related to the facility, the field, and the duration of exposure. The researchers also indicated that congenital malformations were not linked to anesthetic gas exposure. The recommendation was to limit exposure by use of a well-functioning scavenging system, monitoring for waste anesthetic gases, and the use of closed devices such as a cuffed endotracheal tube [10].

### No Association between Waste Anesthetic Gases and Miscarriages

A prospective cohort study was conducted by Lawson, et al. [5]. This study investigated the risk of spontaneous abortion in nurses in the United States with regard to multiple occupational hazards including antineoplastic drugs, anesthetic gases, disinfectants and radiation use. The odds ratio was computed using the SAS software. Early spontaneous abortion was defined as less than 12 weeks gestational age and late spontaneous abortion was defined as occurring between 12-20 gestations. Lawson et al. found that 1.07 odds ratio for a confidence interval 0.81-1.40 produced spontaneous abortions during the first trimester. The investigators concluded that anesthetic gases did not have a significant association with spontaneous abortion especially when compared with other occupational hazards such as radiation [5].

### Waste Anesthetic Gas Effects on DNA

Lucio, et al. [6] reviewed the occupational hazards of waste anesthetic gas exposure in relation to DNA damage and oxidative stress. The article is important to this analysis since potential gene damage may have a devastating effect on fetal development and must be examined as a potential occupational hazard for pregnant anesthesia professionals. This article highlights a research study conducted in 1974 by the American Society of Anesthesiologists, a questionnaire was sent to 49,585 professionals exposed to waste anesthetic gases and compared with 23,911 individuals not exposed to waste anesthetic gases. The exposed group showed an increased risk in spontaneous abortions, children with congenital abnormalities, cancer, and liver and kidney [6]. The researchers also discussed several studies using the comet test to measure Deoxyribonucleic Acid (DNA) damage and evaluate genotoxicity. The tests had concluded that halogenated anesthetics effect the genome at any stage of the cell cycle and cause damage. Another study highlighted by Lucio et al., yielded that in operating rooms with no scavenging system personnel exposed to halogenated gases and nitrous oxide had increased breaks in genetic material, reduced enzyme and antioxidant capacity. The researchers came to the conclusion that chronic exposure to waste anesthetic gases may lead to oxidative stress and potential DNA damage. In 2000, Diana McGregor [8], wrote an article analyzing the health effects of waste anesthetic gases. The author states that research has shown teratogenic effects leading to fetal resorption and fetal development abnormalities when administered at greater than 50% for 24-hour periods in rodents. Rodents also have teratogenic effects when administered enflurane, halothane, and isoflurane. Edmond Eger [3] argues that the use of volatile anesthetic gases poses very low risk for teratogenicity or miscarriage; however, the risk is higher with the use of nitrous oxide. The author states, "nitrous oxide inactivates the enzyme methionine synthase... Methionine synthase facilitates the conversion of homocysteine and methyltetrahydrofolate to methionine and tetrahydrofolate" [3]. During the production of DNA, tetrahydrofolate is a key player and methionine is an essential amino acid. Thus, nitrous oxide interferes with DNA synthesis and may impair fetal development.

Eager [3] also emphasized the Stanford studies [11,12] that researched teratogenic and abortive effects within the dentistry professions. The author highlights that the studies produced evidence of non-dose related teratogenicity in dental assistants. The research determined that dental assistants and wives of dental providers showed a significant increase in spontaneous abortions when directly exposed to nitrous oxide. The increase in exposure level of the male dentist correlated with increased spontaneous abortion in the dentist wives. The Stanford studies, as reviewed by Eager [3] concluded there was not a significant correlation between occupational exposure to anesthesia in the operating room and increased incidence of miscarriages, perinatal death, or neonatal malformations.

### Effects of a Scavenging System

A peer reviewed study was conducted to evaluate the amount of operating room exposure to nitrous oxide [4]. To test the amount of waste anesthetic in the operating room the investigators attached a sample outlet to the end of the scavenging outlet. The investigators used an L connector, sample line, corrugated tube and endotracheal tube to carry out this procedure. The investigators only used five patients and excluded anyone with cardiopulmonary disease, having a laparoscopic procedure, and pregnant. This population does not accurately reflect the general population. Especially with the growing trend of laparoscopic and robotic surgeries. The data was analyzed in ANOVA. For statistical data the INSTAT software was used and a P value of less than 0.05 was considered significant. The researchers determined that fresh gas flow of less than 600 milliliters per minute will need a scavenging system to limit the exposure of nitrous oxide into the air.

McGlothlin, et al. [7] evaluated the amount of waste gas in the post anesthesia care unit, PACU. The study excluded patients with a body mass index great than 40 or any patient with pulmonary disease. The researchers evaluated nineteen patients. A MIRAN 1B SapphIRe Ambient air analyzer was used to quantify nitrous oxide and sevoflurane. The patients were brought to PACU and extubated. Then, the air measurements were taken immediately after extubation, at five minutes, and then in ten-minute increments up to forty minutes. The exposure to nurses were also taken at three- and six-foot intervals. A P value of 0.05 was considered significant. The researchers concluded that there was a significant reduction in the amount of waste anesthetic gases the nurses were exposed to at least 3 feet away from the patient's breathing zone. PACU nurses are exposed to waste anesthetic gases as well and the use of a scavenging system in PACU maybe beneficial in reducing the amount of waste anesthetic gases the nurses are exposed to.

### Limitations

A common theme for limitations in the studies were the studies being retrospective and depended on recall of the participants. Limitations for this analysis were the reliance on mostly seminal work and broad inclusion of a broad range of health professions that may be exposed to waste anesthetic gases.

Analysis of the correlation between spontaneous abortions and exposure to inhaled anesthetics in pregnant healthcare workers was presented in this article with the help of the PICO question, "Does exposure to waste anesthetic gases increase the incidence of miscarriage in female healthcare providers?" The anesthesia community needs clarification on this matter to improve the work environment and reduce the occupational hazards for pregnant healthcare personnel.

### Conclusion

Seminal work indicates that healthcare workers who are pregnant or within childbearing years should minimize their exposure to waste anesthetic gases. Recent research studies also provide significant evidence for an increased risk in spontaneous abortions when providing general anesthesia without utilizing a scavenger system. Along with an increased risk for spontaneous abortions research also provides evidence that waste anesthetic gases, namely nitrous oxide, may lead to impaired fetal development. Recommendations for safe nitrous oxide exposure from the National Institute for Occupational Safety and Health [13] is 25 parts per million and volatile agents exposure level is two part per million. The United Kingdom recommends 100 part per million as the daily limit for nitrous oxide and 50 parts per million volatile anesthetics as opposed to the United States limits, 25 parts per million for nitrous oxide and two parts per million for volatile anesthetics [1]. Majority of the articles suggest the use of a well-functioning scavenging system to minimize exposure to waste anesthetic gases. Other ways to reduce exposure are a closed cuff device like an endotracheal tube, proper fitting face mask on the patient, properly sealed laryngeal mask airway, frequently checked anesthesia and waste anesthetic gas monitoring.

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