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Systematic Review of Occupational and Environmental Exposure to Anesthetic Gases in Operating Rooms: Pregnancy Outcomes in Iranian Healthcare Professionals

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ABSTRACT

Introduction: Operating room personnel are exposed to various occupational hazards that may pose health risks. Advances in anesthetic techniques and ventilation have reduced waste anesthetic gas exposure; however, concerns regarding potential reproductive risks persist. This review aims to summarize the current evidence on occupational exposure to anesthetic gases in operating rooms, focusing on their impact on pregnancy outcomes among healthcare professionals in Iran.

Materials and Methods: A systematic review was conducted on studies published between January 2000 and May 2025, identified through international and Iranian scientific databases, including the Web of Science, PubMed, Scopus, ScienceDirect, SID, Magiran, and IranDoc. Relevant studies were retrieved using keywords such as "Environmental exposure," "Occupational exposure," "Anesthetics," "Operating room," and "Pregnancy outcome" in both Persian and English languages. Finally, five articles were selected for the final analysis.

Results: The reviewed evidence showed mixed results regarding spontaneous abortion and preterm birth rates. Some studies have found a significant association between anesthetic gas exposure and these outcomes, while others have not reported any such association. Two studies have reported a significant association between anesthetic gas exposure and infertility. No significant relationship between anesthetic gas exposure and low birth weight was observed in the studies reviewed.

Conclusion: These findings suggest a potential association between occupational exposure to anesthetic gases and adverse pregnancy outcomes. Given the limited and methodologically limited studies in Iran, further well-designed prospective research and improved workplace safety measures are needed to clarify these associations and minimize the potential risks for operating room personnel.

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Introduction

Operating rooms (ORs) are distinct from other work environments in terms of their construction and working conditions. Moreover, the OR

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environment holds significant importance within hospitals compared to other healthcare ORs, which are distinct from other work environments in terms of their construction and working conditions. Moreover, the OR environment is significantly important in hospitals compared to other healthcare settings [1, 2]. OR personnel are exposed to various hazards that can adversely affect their health. The International Labour Organization (ILO) identifies a range of occupational hazards as serious threats to the health of OR personnel [3]. These include injuries caused by sharp instruments during procedures, exposure to anesthetic gases, radiation, disinfectants, sterilizing agents, and cleaning solutions, all of which can affect the overall health of the personnel [4, 5].

Inhalational anesthetics are pharmacological agents used in patients undergoing surgery under general anesthesia. The primary inhalational anesthetic agents used in clinical practice include NO_2 and halogenated agents. Each of these agents is selected for specific patient populations based on their unique pharmacological properties, advantages, and potential limitations [6, 7]. Nevertheless, small quantities of these anesthetics, known as waste anesthetic gases (WAGs), may escape into the OR. The various health hazards associated with occupational exposure to WAGs among healthcare personnel are still under investigation [8-10]. Several studies have reported that short-term exposure to WAGs may result in adverse effects, including lethargy, headache, fatigue, and nausea. In contrast, prolonged or chronic exposure has been linked to more severe health consequences, such as liver dysfunction and negative pregnancy outcomes [11-14].

Negative pregnancy outcomes, such as infertility, spontaneous abortion, premature birth, and congenital anomalies, have been associated with occupational exposure to inhalational anesthetics. Numerous studies have investigated this association. A survey conducted in the United States, which included 1021 female surgeons from various specialties, found that 35.3% had experienced pregnancy-related complications. This rate is significantly higher than the 14.5% reported in the general population [15]. However, the evidence remains contentious, and considerable debate persists in the scientific community regarding these results. In a systematic review, Oliveira et al. reported that the available evidence was insufficient to conclude whether an association exists between occupational exposure to anesthetics and the occurrence of abortion [16]. In contrast, Nagella et al. reported that the incidence of abortion and birth defects was higher among female anesthesiologists who worked in the OR during the first trimester of pregnancy [17].

Recently, significant advancements have been made in the development of anesthetic agents and clinical techniques. Sevoflurane and desflurane have progressively replaced older agents such as NO_2, enflurane, and isoflurane, and have become the most frequently used inhalational anesthetics in clinical practice. Furthermore, the introduction of novel ventilation strategies by anesthesiologists, along with improvements in filtering and leak alarms, has contributed to the reduction of WAG emissions. Overall, these developments may have resulted in lower WAG concentrations in ORs, consequently mitigating the potential health risks associated with WAG exposure among OR personnel [7, 18].

Despite significant advances in anesthetic techniques and ventilation strategies, which have likely contributed to reduced WAG concentrations in ORs, concerns regarding the potential health consequences of occupational and environmental exposure persist. The discrepancy in the results of previous studies regarding the effects of WAG exposure on pregnancy outcomes among healthcare personnel may be attributed to methodological and environmental differences. Methodologically, variations in study design, sample size, and data collection methods can affect the consistency of the findings. Additionally, environmental factors such as differences in ventilation systems, anesthetic agent usage, and safety protocols across hospitals can influence the concentration of WAGs in ORs, thus affecting the observed health outcomes[19]. Although the long-term effects of WAG exposure, including possible

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carcinogenic risks and adverse pregnancy outcomes, are not yet fully understood, these issues remain subjects of ongoing scientific investigation and debate. Given the high prevalence of exposure among OR personnel and the potential for serious reproductive consequences, including negative pregnancy outcomes, comprehensive research is essential to clarify the extent of these risks. Therefore, this systematic review aimed to summarize the current evidence on occupational and environmental exposure to anesthetic gases in ORs, with a particular focus on their implications for pregnancy outcomes among healthcare professionals in Iran.

Materials and Methods

This review was conducted based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [20]. The search strategy was performed using both Medical Subject Headings (MeSH) and non-MeSH terms. Relevant keywords, such as "Environmental Exposure," "Occupational Exposure," "Anesthetics," "Operating Rooms," and "Pregnancy Outcomes," were searched in various combinations using logical operators (AND / OR) across multiple scientific databases, including Web of Science, PubMed, Scopus, and ScienceDirect, as well as Iranian databases such as SID, Magiran, and IranDoc. Additionally, Google Scholar was used as a supplementary search tool to identify all studies that reported occupational exposure to inhalational anesthetics and pregnancy outcomes. The inclusion criteria were articles published between January 2000 and May 2025, studies examining occupational exposure to inhalational anesthetics and pregnancy outcomes in the Iranian population, and studies that had full text and sufficient data. The exclusion criteria were duplicate articles, irrelevant studies, and those lacking sufficient scientific quality to be included. In the database search, 2618 relevant articles were identified. Titles and abstracts were screened to exclude studies that did not meet the relevant criteria. Subsequently, the full texts of the remaining articles were reviewed, and five articles were selected for the final analysis. The study selection process is shown in Figure 1. The collected data were categorized according to pregnancy outcomes.

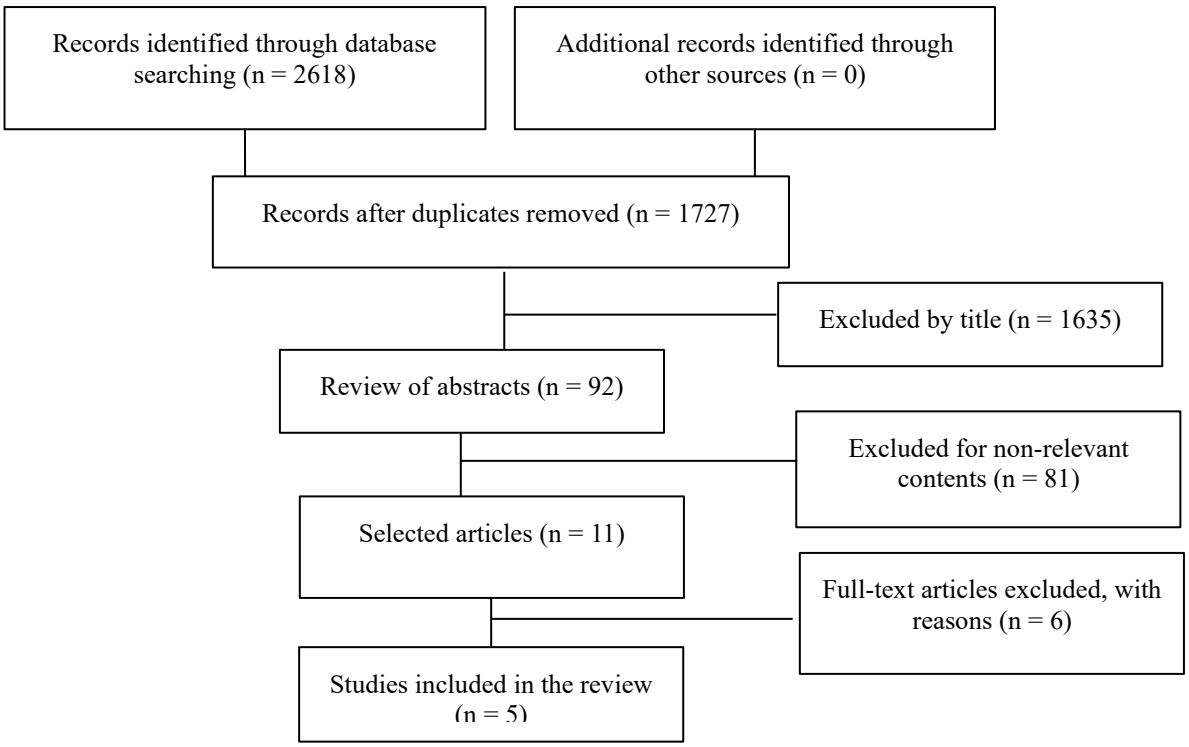

Figure 1: Study selection flow chart.

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Results

Based on this review, few studies have been conducted in Iran to determine the effect of exposure to anesthetic gases on pregnancy outcomes among operating room personnel. Each of these studies addressed one or more pregnancy outcomes, which include a wide range of problems, including spontaneous abortion, preterm delivery, infertility, low birth weight, and so on. The characteristics of the included studies are summarized in Table 1.

Table 1: Summary of Characteristics of Included Studies

Authors and year	Study design	Province	Exposed group	Non-exposed group
Aminian et al. 2007[21]	Historical cohort	Tehran	198 operating room personnel	201 nurses working in the emergency department, ICU, and CCU
Nanbakhsh et al. 2008[22]	Case-control	West Azerbaijan	118 operating room personnel	180 nurses working in the other wards
Amini and Savaie 2011[23]	Case-control	Fars	122 operating room personnel	122 women working in internal medicine and pediatrics wards
Najafian and Ghomeishi 2013[24]	Case-control	Khuzestan	250 operating room personnel	250 women working in internal medicine, pediatrics, and obstetrics wards
Moharrami et al. 2023[25]	Retrospective cross-sectional	Razavi Khorasan	153 health care personnel	

Discussion

Spontaneous abortion

Spontaneous abortion is the most common complication of pregnancy, often with no clear cause, and various genetic, hormonal, environmental, and occupational factors can affect its occurrence [26-29]. This phenomenon is generally referred to as the unwanted termination of pregnancy before 20–22 weeks [30]. In many studies, exposure to anesthetic gases has been identified as a potential risk factor. In studies conducted in Iran, there is no complete consensus on the existence of a significant relationship between the exposure of operating room personnel to anesthetic gases and an increased risk of spontaneous abortion. In the study by Nanbakhsh et al., the probability of abortion in working women exposed to these gases was three times that of the control group [22]; Najafian et al. also reported this rate to be approximately two times [24]. In both studies, a statistically significant relationship was observed between occupational exposure to anesthetic gases and an increase in spontaneous abortion ($p < 0.05$). In three other studies, no statistically significant association was found ($p > 0.05$), but in all of them, the number of miscarriages was higher in the exposure group than in the control [21, 23, 25]. The findings of Iranian studies on anesthetic gas exposure and spontaneous abortion are summarized in Table 2. These discrepancies seem to be related to the limitations of the study design, small sample size, and difficulty in controlling for confounding factors. Therefore, larger and more carefully designed studies are still necessary.

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Table 2: Findings of Iranian Studies on Anesthetic Gas Exposure and Spontaneous Abortion

Authors	Abortion rate and p-values (comparison between exposed and control groups)
Aminian et al.[21]	Exposed group: 15.7% Non-exposed group: 13.4% $p = 0.529$
Nanbakhsh et al.[22]	Exposed group: 22.8% Non-exposed group: 7.6% $p < 0.05$
Amini and Savaie[23]	Exposed group: 19.8% Non-exposed group: 16.0% $p = 0.089$
Najafian and Ghomeishi[24]	Exposed group: 18.7% Non-exposed group: 9.1% $p < 0.05$
Moharrami et al.[25]	Total population: 3.9% $p > 0.05$

Preterm birth

Prematurity is one of the most important causes of mortality and disability in infancy and childhood [31, 32]. Premature infants are at risk of chronic health problems and functional limitations throughout their lives due to the lack of proper organ development and greater vulnerability to infections [32, 33]. Studies have shown that in Iran, most studies have failed to show a significant association between exposure to anesthetic gases and preterm birth in operating room personnel [22-24]. However, Moharrami et al. reported a significant association between these two variables in their study ($p < 0.015$)[25]. The findings of Iranian studies on anesthetic gas exposure and preterm birth are summarized in Table 3. It seems that the difference in study results is due to the limited number of registered cases of preterm birth and weaknesses in study design, such as the lack of an appropriate control group in this study. This suggests that future studies should be conducted with larger samples and stronger epidemiological designs to achieve more definitive results.

Table 3: Findings of Iranian Studies on Anesthetic Gas Exposure and Preterm Birth

Authors	Preterm birth rate and p-values (comparison between exposed and control groups)
Nanbakhsh et al.[22]	Exposed group: 4.2% Non-exposed group: 2.4% $p = 0.229$
Amini and Savaie[23]	Exposed group: 7.0% Non-exposed group: 9.2% $p = 0.557$
Najafian and Ghomeishi[24]	Exposed group: 8.2% Non-exposed group: 7.9% $p = 0.517$
Moharrami et al.[25]	Total population: 9.8% $p = 0.015$

Infertility

According to the World Health Organization (WHO) and the International Committee for the Monitoring of Assisted Reproductive Technologies (ICMART), infertility is defined as the failure of couples to conceive after 12 months of unprotected sexual intercourse [34]. This global problem can be influenced by several factors, including lifestyle characteristics, environmental conditions, and occupational factors [35]. In Iran, only two studies have investigated the association between occupational exposure to anesthetic gases and infertility in operating room personnel, and both studies reported a statistically significant

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association between this exposure and increased infertility ($p<0.05$)[23, 24]. Table 4 presents the findings of Iranian studies on anesthetic gas exposure and infertility. Although these findings are of particular importance, due to the limited evidence, further research is needed to clarify the mechanisms involved and to definitively confirm this association.

Table 4: Findings of Iranian Studies on Anesthetic Gas Exposure and Infertility

Authors	Infertility rate and p-values (comparison between exposed and control groups)
Amini and Savaie [23]	Exposed group: 8.2% Non-exposed group: 2.5% $p = 0.046$
Najafian and Ghomeishi [24]	Exposed group: 14.3% Non-exposed group: 4.3% $p < 0.001$

Low birth weight

Proper fetal growth is one of the most important factors in ensuring the survival, health, and quality of life of newborns. Low birth weight (LBW), a key indicator of newborn health, is directly related to an increased risk of mortality and morbidity during and after infancy and can have long-term negative effects on various aspects of a person's health in adulthood [36]. Based on a review of domestic studies, none of the studies conducted in Iran have shown a statistically significant association between occupational exposure of operating room personnel to anesthetic gases and LBW ($p > 0.05$)[23, 24]. The findings of Iranian studies on anesthetic gas exposure and LBW are presented in Table 5. However, some international studies have reported an increased risk of low birth weight among women working in operating rooms. This issue highlights the need for larger and more comprehensive studies to determine whether this association is specifically related to anesthetic gas exposure or influenced by other occupational and environmental factors.

Table 5: Findings of Iranian Studies on Anesthetic Gas Exposure and Low Birth Weight (LBW)

Authors	LBW newborn rate and p-values (comparison between exposed and control groups)
Amini and Savaie[23]	Exposed group: 6.9% Non-exposed group: 8.6% $p = 0.737$
Najafian and Ghomeishi[24]	Exposed group: 7.8% Non-exposed group: 8.2% $p = 0.636$

Conclusion

Based on the review, studies conducted in Iran show that exposure of OR personnel to anesthetic gases can be associated with some pregnancy outcomes, including spontaneous abortion and infertility, while the evidence regarding preterm delivery and low birth weight infants is inconsistent, and often no statistically significant association has been reported. However, the results of some studies in Iran, as well as international studies, have indicated an increased risk of adverse pregnancy outcomes in working women exposed to these gases, highlighting the importance of this issue.

Existing studies have important limitations. Small sample sizes, cross-sectional designs, and difficulty in controlling for confounding factors such as gestational age, health status, lifestyle, and factors related to the individual's spouse have reduced result accuracy. In addition, heterogeneity in the environmental and technical conditions of ORs is one of the main reasons for the differences

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in the findings. The quality and efficiency of ventilation systems, presence or absence of anesthetic gas removal equipment, differences in the model and technology of anesthesia machines, and even the working methods of personnel are factors that significantly affect the actual level of exposure and cause inconsistencies in the results. In addition, many studies have been conducted based on questionnaires or self-reports and have used fewer biological and environmental monitoring methods, which can lead to errors in estimating the level of exposure.

Therefore, prospective studies with large cohorts and more precise designs are necessary to accurately examine the cause-and-effect relationship between exposure to anesthetic gases and pregnancy outcomes. In addition, regular environmental and biological monitoring of anesthetic gases, considering the systemic and technical differences in ORs and controlling for individual and occupational variables, can help clarify the results. Examining the long-term consequences in the children of this group of mothers is also of great importance. Overall, although the available evidence is not conclusive, the existing concerns require improving safety standards, improving ventilation systems, proper use of anesthesia equipment, and creating a culture in this area to be seriously considered by relevant institutions to minimize the potential risks for working mothers and their children. In addition, based on a review of the available national guidelines and regulatory documents, there appears to be no mandatory standard or formal directive in Iran that specifies the permissible concentrations of anesthetic gases in the OR air. Therefore, it is highly advisable that a dedicated policy or practical guideline be developed to clarify the acceptable exposure limits, monitoring protocols, and control criteria for anesthetic gases in ORs.

Abbreviation

ICMART: International Committee for the Monitoring of Assisted Reproductive Technologies
ILO: International Labour Organization
LBW: Low birth weight
OR: Operating Room
WAG: Waste Anesthetic Gas
WHO: World Health Organization

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Conflict of Interest

The authors declare no competing interests.

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Ethical Considerations

Not applicable.

Code of Ethics

Not applicable.

Authors contribution

MJ, FMS, and ZS conceptualized and designed the study. FMS and AG performed the literature search and screened the studies for eligibility. All authors analyzed the data and wrote the manuscript. The authors met the criteria for authorship and played a role in preparing the manuscript. All authors have approved the final manuscript.

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