Investigation of nitrous oxide concentration in operating rooms of educational hospitals of Ahvaz Jundishapur University in year 2012

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ABSTRACT

Nitrous Oxide gas can affect the patient and also cause chronic complications in operating room staff in the short term. In the current survey, we measured the Nitrous Oxide gas levels in the operating room of the educational hospitals of the Ahvaz Jundishapur Medical University.

576 samples were taken from 32 operating rooms through 4 months. Sampling was done in 3 different working times (8:30-9:00, 10:30-11, 12:30-13:00) from 6 different sites in the operating room. Portable infrared spectrophotometer was used for measuring the concentration of nitrous oxide. The apparatus was calibrated by Nitrous Oxide gas capsule before each reading.

Variance analysis was used to compare the means of Nitrous Oxide levels between places of sampling in the operating rooms. There was a significant difference between these amounts ($p \leq 0.00$). Then LSD analysis was used to locate the variation factor. The exhaust of the anesthesia machine was the most noted place ($p \leq 0.0001$) and the other places did not show significant differences. There was a significant difference between measurements recorded when the air-conditioning system was on or off and if there was an air-conditioning system or not. These differences were observed at all the measurement times.

According to the results from the current study, levels of Nitrous Oxide in operating rooms were higher than that recommended by international organizations (25 ppm) and it appears that exposure to this amount of gas could be potentially harmful for staff. It is recommended to take special safety measures and prevent the gas to be increased in the operating room using air conditioning and proper ventilation of the room.

Keywords: Nitrous oxide, Anesthesia gas, Operating room, measurement, Ahvaz

INTRODUCTION

Nitrous Oxide is the most common anesthetic gas currently in use. Although inhalation anesthetics diethyl ether, nitrous oxide and chloroform have been used since 1840, the biological effects of occupational exposure to anesthetic agents remained unstudied until 1960. There have been reports on epidemiology, in vitro cellular and animal studies of exposure to anesthetic agents (1).

Using nitrous oxide during general anesthesia reduces the pain and lessens the use of other agents. Using this gas could induce short term and long term side effects. Its short term side effects include a decrease in the renal and hepatic blood flow, and transient changes in the liver function tests during surgery (1, 2). Besides its short term effects, nitrous oxide also has some long term effects which mainly affect the people working in the operating room. Carcinogenesis is one of these effects. Epidemiological studies suggest that staff with exposure to even low levels of inhalation anesthetics have higher rates of cancer (2).

Ellen Regina da Costa Paes *et al.* reported that exposure to anesthesia gases including nitrous oxide can cause DNA damage, increase plasma thiols and enzyme glutathione peroxidase GPX was higher at 16 and 22 months of exposure (3). Head BP, *et al.* concluded that nitrous oxide does have an additive toxicity effect when combined with other anesthetic agents (4). Long term exposure to nitrous oxide has detrimental effects on the genital system of the operating room staff (5) and evidently lowers the fertility (6) and increases the number of miscarriages (7). These aberrations which are recorded from different studies, attributes them to changes induced by nitrous oxide. Increased frequency of aberrations in chromosomes and sister chromatids is also repeatedly reported in people working in the operating room who are exposed to nitrous oxide alone or in combination with other halogenated gasses (8-11). Long term exposure to this gas could inactivate the methionine synthase and cause megaloblastic anemia through oxidation of vitamin B12 (12). Other side effects include lower mental performance, vision and hearing performance lowering, attention defect, dizziness, drowsiness, excitability, and behavioral disorders (13).

Air-conditioning systems cannot exhaust the gas from the operation room. Therefore, the National Institute for Occupational Safety and Health (NIOSH) has set 25 ppm as the maximum acceptable level of the gas in the operating room (14). This amount is 100 ppm for European countries like Germany, UK and Sweden (15). In Denmark, this level is 50 ppm and the levels more than 100 ppm is only acceptable for exposure times less than 15 minutes (16). During the last decades, using air-conditioning systems, low-flow anesthesia and intravenous anesthesia have decreased the pollution in the operating room and subsequently occupational exposure of people working in the operating room (17, 18). Despite progresses, occupational exposure to inhalation anesthetics among the operating room staff persists (19, 20). Therefore, systems for exhaustion of anesthetic gasses are demanding (21).

As nitrous oxide is being used in the operation room currently and there has not been a study of its concentration in operating room air of educational hospitals of Ahvaz city, we decided to assess the occupational exposure to this gas in the hospitals.

MATERALS AND METHODS

Sampling

This cross-sectional observational study was conducted in 32 operating rooms of Imam Khomeini, Golestan and Razi hospitals.

Nitrous Oxide was being used by flow of 2-3 liter per minute as an anesthetic agent in all of the operating rooms which were studied. Portable infrared spectrophotometer model 3010 (Wavelength infrared nitrous oxide sensor) of Bacharach Company was used for sampling and measurement of nitrous oxide concentration. Before each measurement, the apparatus was calibrated with nitrous oxide capsule. The calibration gas flow was not more than 120 cc/min. Measurement error of the instrument was ±5ppm (22). Sampling day was chosen randomly for each measurement. During 4 months 576 samples were collected from 32 operating rooms. Sampling was done in 3 different times of the working hours [from 8:30-9:00 (time 1), 10:30-11:00 (time 2), and 12:30-13 (time3)]. Sampling sites included:

1. 5 cm distance from excretion exhaust
2. 5 cm distance from air conditioning system exhaust
3. 15 cm from surgeon breathing zone
4. 15 cm from nurse breathing zone
5. 5 cm from anesthesia technician breathing zone
6. 5 cm from endotracheal tube or anesthesia mask (23, 24).

Time Weighted Average (TWA) calculation

Based on following equation TWA was calculated:

$$\text{TWA for 8 hours} = \frac{t_1 c_1 + t_2 c_2 + t_n c_n}{8\ \text{hr}}$$

Statistical Analysis

Mean of nitrous oxide gas concentration in different conditions was compared using independent samples t-test or one-way ANOVA. Statistical analysis was done in the SPSS version 19 (IBM Corporation, USA). P values less than 0.05 considered significant. Possible effects of ventilation system, cooler, and exhaust system were also assessed. The standard air conditioning system was defined as an entry from the roof and two exits from the floor with 10-20 times air exchange of the room per minute.

RESULTS

In the current study, 32 samples were taken from operating rooms in the hospitals of study. The mean temperature of the operating rooms in the working hours was 23.25±1°C (minimum: 22 °C and maximum: 25 °C). Mean area of the rooms studied was 30.40±11.6 square meter . Absolute and relative frequency distribution of the rooms studied is tabulated in table 1.

Table 1: Frequency and percentage of studied operating rooms

Hospital	Operating Room	Frequency	Percent
Imam Khomeini	General	11	34.37%
Imam Khomeini	Eye	4	12.50%
Imam Khomeini	Infertility	2	6.25%
Golestan	General	8	25%
Golestan	Renal Graft	2	6.25%
Razi	General	5	15.63%
Total		32	100%

65% of the rooms had ventilation system and the ventilation systems were active in only 21% of these rooms. The cooler was on in 75% of these rooms and the exhaust system was working at 47% of these rooms (table 2).

According to the results, 25% of the sampling units had a scavenging system for extra anesthetic gasses and in 18% these systems were not connected to the anesthesia machine.

For comparing the means of the concentrations of the nitrous oxide between the sampling points, variance analysis showed significant differences ($p \leq 0.000$). Then LSD (Least Significance difference) analysis of the differences between measured points showed that the area around the anesthesia machine exhaust has significant difference ($p \leq 0.0001$). Other places did not show any significant differences (table 3).

Table 2: Absolute and relative distribution of the operating rooms according to the state of their ventilation system, cooler and exhaust systems

	Condition	Frequency	Percent
Ventilation System	ON	7	21
	OFF	14	44
	Not exist	11	35
Cooler	ON	24	75
	OFF	4	12.5
	Not exist	4	12.5
Exhaust System	Connect	15	47
	Not Connect	11	35
	Not exist	6	18

The mean of nitrous oxide concentration in different site of the operating rooms was shown in table 4. The results showed that concentration of nitrous oxide was different with the changes of sampling site and concentration in sites without a standard ventilation were more than their in sites with the standard system.

Table 3: Concentration of Nitrous Oxide (ppm) in different sites of the operating room

Sampling site	No.	Mean	S.D.	Min.	Max.
Site 1	96	2978	4313	5	9999
Site 2	96	364	379	0	1500
Site 3	96	126	128	5	510
Site 4	96	130	151	5	1035
Site 5	96	198	179	0	780
Site 6	96	150	98	10	420

Table 4: Mean of the Nitrous Oxide concentration (ppm) in the different sites of the operating rooms with or without standard ventilation

Sampling site	Ventilation system	Mean	Standard Deviation	$P_{.value}$
Site 1	standard	159.28	275.91	0.01
	Not standard	3768.25	4580.35	
Site 2	standard	224.28	483.58	0.325
	Not standard	403.66	337.96	
Site 3	standard	36.42	43.70	0.01
	Not standard	151.09	133.36	
Site 4	standard	82.61	220.91	0.891
	Not standard	143.93	124.94	
Site 5	standard	63.09	63.27	0.001
	Not standard	236.40	183.63	
Site 6	standard	147.38	78.51	0.051
	Not standard	151.33	95.31	

In operating rooms with active standard ventilation, mean of nitrous oxide concentration in three times were 63.09±63.27 ppm in the breath area of the anesthesia technician, 36.42±43.70 ppm in the breath area of the surgeon, and 82.61±220.91ppm for the breath area of the operating room nurse. Concentration of nitrous oxide in operating rooms with non-standard ventilation was 236.40±183.63 ppm, 151, 09±133.36 ppm, and 124.94±143.93 ppm, respectively (table 4).

Status of the ventilation system including on or off state was also assessed in the current study. As can be seen in the table 5, there was a significant difference between the concentrations of the nitrous oxide in the operating rooms with ventilation with those without ventilation. There were also significant differences in the mean of nitrous oxide concentration between the ventilation on and off states of the rooms. These differences were observed during the study in all times of the sampling.

Table 5: Status of the ventilation system in the time of sampling and its effects on the concentration of nitrous oxide

	Condition	No.	8:30-9:00 (Mean±SD)	10:30-11:00 (Mean±SD)	12:30-13 (Mean±SD)	Mean of Times
Ventilation System	ON	42	101±255	۱۰۸±211	۱۲۱±250	۱۱۰±228
	OFF	84	۱۰۳۲±2728	۹۷۸±۲۰۳۱	۹۹٥±2527	۱۰۰۱±2587
	Not exist	66	۳٤۳±1232	٦٥٥±2066	٦۹٤±2061	٥٦٤±1826
P.value			۰,۰۱۲	۰,۰۲۷	۰,۰۲۷	۰,۰۰۰

Concentration on nitrous oxide in the different hospital's operating rooms in different sampling time was shown in table 6. To compare the means of nitrous oxide concentrations in the eye operating rooms, transplantation, general and IVF in the Imam Khomeini, Golestan and Razi hospitals we used ANOVA analysis. These analyses showed no significant differences between these amounts except for the transplantation room for which the concentration of gas in the first time was significantly more than others. This could be due to the fact that the transplant surgery is done during the first time and there was no operation in the other times. It was also due to the lack of ventilation system and the small rooms.

8 hr. TWA for all the operating rooms is shown in table 7. The results showed that concentration of nitrous oxide in IVF of Imam Khomeini was more than its in other operating rooms.

Table 6: Comparison of Nitrous Oxide concentrations (ppm) in the different hospital's operating rooms in different sampling times

	Eye (Imam Khomeini)	Transplantation (Golestan)	General (Imam Khomeini)	General (Golestan)	General (Razi)	IVF (Imam Khomeini)
Time 1	35.83±50.66	1135.75±2808	1194.59±3058	228.85±311	170.166±270	1976.50±3748
Time 2	41.87±56.64	423.33±373	1098.01±2843	242.91±274	203.33±291	1998.53±3658
Time 3	48.12±60.73	443.91±362	1412.83±3219	267.18±314	242.00±326	2059.00±3710
P.value	0.75	0.491	0.831	0.819	0.646	0.998

Table 7: Mean concentration of Nitrous Oxide (8hr TWA) in all operation rooms (ppm)

	Eye (Imam Khomeini)	Transplantation (Golestan)	General (Imam Khomeini)	General (Golestan)	General (Razi)	IVF (Imam Khomeini)
Time 1	35.83±50.66	1135.17±2808	1194.59±3058	228.85 ±311	170.166 ±270	1976.5 ±3748
Time 2	41.87±56.64	423.33±373	1098.01 ±2843	242.91±274	203.33 ±291	1998.53 ±3658
Time 3	48.12±60.73	443.91±362	1412.83 ±3219	267.18 ±314	242.00±326	2059 ±3710
8hr TWA	41.17	695	1212.93	243.71	200.56	2005.39
average	41.94	664.33	1235.14	246.31	205.17	2010.67

DISCUSSION

Results show that the mean and Time Weighted Average (TWA) of nitrous oxide in all three different measurement times were much higher than the standards set by NOISH (25 ppm). According to the results in table 5, using a standard ventilation system significantly decreased the amount of waste gas at all times of measurement. This is in compliance with the study by Mierdl *et al.* (25) although, in the study of Seddigh Maaroufi *et al.* showed that 58% of rooms with ventilation system had much higher levels of Nitrous Oxide (13). In the current study, it was also demonstrated that 35% of the operating rooms did not have ventilation systems and only in 21% of the remaining 65% rooms had an active ventilation system. In the rest, ventilation systems were off and they were not used for exhaustion of waste gases.

According to the recommendations by NOISH, if appropriate scavenging system and proper ventilation of the operating room are considered (20 times of air exchange in an hour, with air channel in the roof and an air exit window in the ground) then, the mean concentration of nitrous oxide in the operating rooms will be in the recommended account (26, 27).

Therefore, using scavenging systems for reducing the contamination of air in the operating rooms are necessary and could prevent the long term and short term effects of this gas. For example, in a study by Van Der Kooy *et al.* in 2012 conducted the effect of using scavenging systems in the operating rooms on reduction of nitrous oxide levels in the operating rooms in which pregnant women were being anesthetized using this gas. Results showed that scavenging can effectively reduce the nitrous oxide pollution in the operating room (28).

Raj *et al.* showed that use of air cleaner systems in the operating rooms effects on the level of Nitrous Oxide gas in the room and the exposure of operating room staff with it (29).

Borganelli and colleagues demonstrated that if appropriate ventilation with high suction power is used, significant decrease in the level of nitrous oxide in the operating room is possible. They suggest that ventilation system and the amount of suction of scavenging system are the most

important factors in the reduction of nitrous oxide pollution to the level accepted by NOISH (30).

According to the results in the tables 3 and 4, most polluted area is the exhaust releasing the anesthetic agents which show the leak around the anesthesia machine. In a study which assessed the relationship between leakage of the anesthesia machine and the nitrous oxide concentration, a direct relationship between these two factors were found (31). Monitoring of the anesthetic gasses which included the assessment of anesthesia machines, scavenging system and the ventilation system, should be done continuously in the operating rooms.

According to the other results that were shown in the table 5, there was a significant difference between three measured amounts in different sampling times in rooms lacking proper ventilation, because of lack of ventilation system or inactive ventilation system. These results are in compliance with other studies in this field (23, 24).

These evidences show that the staff especially anesthesia technician are exposed to high concentrations of this gas operating room during the working day. This long term exposure could have detrimental effects on their health. For example, in a study on women who had exposed to nitrous oxide for more than 3 hours in a week by Rowland *et al.* they found that the relative risk of miscarriage in these women compared to controls was 2.6 (confidence interval: 1.3-5). This risk was not observed in the people who were using air cleaning systems in their working environment. Researchers found that using refinement systems can have a major effect on the exposure to this gas and prevent the infertility of female working in the places which nitrous oxide is being used (7).

Study of Wronska-Nofer *et al.* demonstrated a direct relationship between nitrous oxide concentrations and the oxidative damages of the DNA in the staff that they were working in the operating room (5).

According to the table 6, nitrous oxide levels did not show significant differences in three different sampling time points in all rooms except the ophthalmic operating room of the Imam Khomeini Hospital, which the nitrous oxide concentration was below European standards, 100 ppm, and in the restrooms, concentration of nitrous oxide was higher than its European standards. As ventilation system is appropriate in all of the ophthalmic operating rooms of the Imam Khomeini hospital, there is a difference between these rooms and other rooms as can be seen in the table 6.

In total, high concentrations of nitrous oxide in the operating rooms of these 3 hospitals in Ahvaz, which significantly exceed of allowed amounts, could cause various complications in the staff that worked in operating rooms. It is recommended that different methods can be used to prevent the increasing amount of anesthetic gasses in the operating rooms. During current study it was observed that many of the anesthesia machines did not have exhaust tube or if they had, the tube was not connected to the machine. The staff was working in operating room, usually ignoring these facts. It is also possible that they were unaware that disconnecting exhaust tube from anesthesia machine can cause accumulation of anesthetic gasses in the room which may be harmful for them. Therefore, it is necessary to train the staff on risk factors, methods of refining air, correct methods of maintenance of devices and also warn them about the side effects of long term exposure to these gasses. It is necessary to assess the ventilation systems in a distinct time intervals. Use of powerful scavenging systems is also a recommendation to reduce the risks of occupational exposure to anesthetic gasses.

CONCLUSION

In the current study, we found that the concentration of nitrous oxide in the operating rooms of the studied hospitals was significantly higher than recommended standards by international organizations. These high amounts of anesthetic gasses can have detrimental effects on the health of staff in the operating room. Therefore, it is necessary to pay more attention to the occupational safety of the staff and reduce the level of these gasses through using systems for collection and removal of them. By constitutive control and proper maintenance of devices and ventilation systems, it is possible to keep the nitrous oxide pollution as low as possible. It is also necessary to train staff for proper maintenance of devices and methods for reduction of exposure to these gasses. Warning staff about complications associated with long term exposure to nitrous oxide is also necessary.

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