Nitrous oxide in waste anesthetic gases with different fresh gas flow: a case-based pilot observation and a practical thought on scavenging

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Abstract

Use of nitrous oxide (N_2O) as an anaesthetic gas has been on contradicting views for various reasons; operating room (OR) pollution and occupational exposure is one of those controversies. The present pilot experiment was planned to analyze the anaesthesia gas waste at the machine end of scavenging outlet and calculate the probable portion of N_2O in the OR air, which is likely to help us in informed decision making. Anaesthesia gas waste was sampled at the machine end of scavenging outlet and was connected directly and analyzed using a gas analyzer attached to Mindray A7 anaesthesia workstation. An assembly of L connector, sampling line, corrugated tube and endotracheal tube were used to perform the procedure. The measurements were taken at 600, 1200 and 1800 mL/minutes of fresh gas flow (FGF). A total of 15 paired readings from five general anaesthesia cases were taken. The N_2O percentage in the anaesthesia 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. On calculation, the likely concentration of N_2O in OR with FGF of 600 mL/min is 0.576 ppm, which will lead to the time weighted average 4.6 ppm exposure per day in modular OR. Reducing FGF to 600 mL/min reduces the N_2O concentration in OR by 75% as compared to the FGF of 1800 mL/min. The time weighted average exposure to N_2O is far below the permissible limit in modular OR.

Key words: nitrous oxide; occupational exposure; operating rooms; low flow anesthesia; anesthetics, inhalation; operating theater complex; occupational hazards; waste anesthetic gases

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INTRODUCTION

Nitrous oxide (N_2O) is one of the oldest inhalational anaesthetic agents used in modern anaesthesia practice. However, it has been on and off the list of drugs in the anaesthesiologists armamentarium for various contradicting views. Issues like adverse effects on the patient, environment pollution and safety to the operating room (OR) workers are always haunting this agent and anaesthesiologists decades after decades.¹ After the publication of ENIGMA-II trial, there has been a renewed interest on this time tested agents safety.² Moreover, current anesthetists are practicing low and minimal flow anaesthesia more often.³ Therefore the question of OR and environment pollution as well as exposure of OR working personals also needs to be reconsidered. It is well known and expected that the amount of N_2O in the scavenging end or anaesthesia gas waste will be lower in minimal and low flow anaesthesia as compared to conventional flow anaesthesia. Some anaesthesiologists even goes ahead with a statement that the use of scavenging system may not be even necessary when the air handling unit (AHU) is functioning. However, the exact measurement of the fraction of N_2O in the anaesthesia gas waste is hardly quantified for different flows. The measurement is also likely to give us an idea on the question of needful for scavenging system in modern OR. Therefore the author planned to analyze the anaesthesia gas waste at the machine end of scavenging outlet and calculate the probable portion of N_2O in the OR air.

SUBJECTS AND METHODS

Study participants

Departmental permission and patients consents were obtained. This observation was a part of an academic teaching-training program for demonstrations of minimal, low and conventional flow anaesthesia. Five adult patients, who underwent non-cardiothoracic surgery under volatile anaesthetic based general anaesthesia with N_2O as balanced gas, were included for demonstrations. Patients who were having cardiopulmonary disease, laparoscopic surgery, and pregnancy were not included. For this a corrugated short tube was connected to an "L" connector with connection for anaesthesia gas sampling. The gas sample line was connected to anaesthesia gas analyzer attached to Mindray A7 (Mindray Medical International Limited, Shenzhen, China) anaesthesia workstation on the other end. An endotracheal tube was connected to the "L" connector to act as reserve during the inspiratory phase when no waste gas will be vented out through the scavenging outlet so that room air is not aspirated by the anaesthesia gas analyzer (**Figure 1**). The suction rate was set at low. A total of three reading for the fraction of N_2O in waste gas was taken at 1800, 1200 and 600 mL/min fresh gas flow (FGF) in each patient (**Figure 2**). The first reading was taken once the patients MACage was 1.1 to 1.2 with inhalational agent at equilibrium Fe (fraction of expired)/ Fi (fraction of inspired) agent > 0.8 and Fi and Fe of N_2O was 55–62% and 54–60%, respectively. After changing the FGF, a latent period of 20 minutes was given before the

Figure 1: Gas sampling assembly from scavenging port along with readings in the monitor.

Figure 3: Nitrous oxide (N_2O) in the anaesthesia gas waste with different fresh gas flows (FGF).

Note: The data were analyzed using one-way analysis of variance and paired *t* test.

reading was taken for the next respective flows. The proportion of oxygen and N_2O was changed minimally during the study time to keep the F_i and F_e of N_2O within the mentioned limit. The data collected were noted in Microsoft excel and analyzed using one-way analysis of variance (ANOVA) and paired *t* test. INSTAT software, version 1 (GraphPad Prism Software, La Jolla, CA, USA) was used for statistical measurements and a *P* value of < 0.05 was taken as significant.

RESULTS

A total of 15 paired readings from 5 general anaesthesia (GA) cases were taken. Sixty percent patients under anaesthesia were male. The age, weight and body mass index of the patients were 49.8 ± 9.14 years, 56.4 ± 5.68 kg and 22.39 ± 1.16 kg/m² respectively. The percentages of N_2O in the anaesthesia gas waste are presented in clustered column (Figure 3). The N_2O percentage in the anaesthesia waste gases with a FGF of 600, 1200 and 1800 mL were 3.4 ± 0.54 , 8.2 ± 0.83 and 14.0 ± 0.70 , respectively and there is a significant difference among the three groups ($P < 0.0001$, one-way ANOVA with post test).

Figure 2: Hierarchy flow chart for data collection.

When compared with 600, both 1200 and 1800 mL groups showed significant difference ($P < 0.0001$, paired *t* test). The similar significance was also seen when compared 1200 mL with 1800 mL group ($P < 0.0001$, paired *t* test).

DISCUSSION

In the present observation, when FGF was reduced by 33% from 1800 mL, the N_2O percentage in the anaesthesia waste gases reduced by 41.4%. Similarly, 50% reduction of FGF from 1200 mL, the N_2O percentage in the anaesthesia waste gases reduced by 58.5%. These findings indicate that the reduction of N_2O percentage in the anaesthesia waste gases is more than the percentage of FGF reduction. Now the question arises, whether the amount with FGF 600 mL/min is significant hazard in the OR where scavenging system is not in place?

Assuming a closed circuit, the entire FGF of 600 mL/min given to the patient will not be vented out from the scavenging port. This is because, a portion of inspired oxygen will be consumed by the patient and in turn carbon-di-oxide will be produced by nearly 85% (*i.e.*, respiratory quotient) of the oxygen consumed and added to expiratory gases. However, nearly entire amount of carbon-di-oxide will be neutralized by carbon-di-oxide absorber. For example, if a 50 kg person is ventilated with 8 mL/kg tidal volume at a rate of 12 breaths per minute, the minute ventilation will be 4800 mL. The oxygen consumption under GA varies from 4 to 5% during maintenance. Assuming fraction of inspiration oxygen concentration (F_{iO_2}) of 45%, the fraction of expired oxygen concentration (F_{eO_2}) will be 40%. The oxygen consumed by the patient therefore will be 240 mL; oxygen consumption (VO_2) = $V_{Exp} \times (F_{iO_2} - F_{eO_2})$. The carbon-di-oxide produced will be 204 mL and expected to be neutralized by absorber. So, approximately 360 mL of gases ($600 - 240 + (204 - 204)$) will be vented out. Among these 360 mL, 3.4% is N_2O (as shown in the present experiment with 600 mL/min FGF), which indicates that the amount of N_2O is 12.24 mL. The average OR floor area mea-

tures about 600 square feet (56 m²).⁴ Taking a ceiling height of 10 feet and 75% is occupied by air, the volume of the room occupied by air is 4500 cubic feet (127.43 m³), which equals to 127,430 L. As the AHU of OR replaces room air nearly 10–12 exchange per hour⁵; the OR volume is expected to be replaced every 6 minutes. In other words, the amount of N₂O volume available in the OR at a time will be amount vented out in 6 minutes; *i.e.*, 73.44 L or 73,440 mL. If converted to ppm, this is likely to give a figure of 0.576 ppm. Considering the 8 hours duty per day, the time weighted average will be 4.6 ppm only which is far below the permissible exposure limit.⁶

Moreover, in modern modular OR, the fresh air flows from the ceiling above the patient vertically and flows away towards the wall producing an air curtain. Although the present observation is limited with the fact that the air was not sampled from the workers breathing zone, the exposure limit even though is expected to be variable, it unlikely to be more than this as most of the workers in OR works within air curtain. However, more precise measurement can be done by using an infrared spectrophotometer which will help us taking a strong decision. We have not also measured the N₂O level at relatively high flow during induction.

In summary, a FGF of 600 mL/min or less is likely to take out the need of scavenging system in a modular OR with functioning air handling unit.

Author contributions

HMRK conceived and designed the study, collected the data, searched the literature, wrote-up, reviewed and edited the manuscript. MK designed, collected the data, and wrote-up the manuscript. Both of them approved the final version of the manuscript for publication.

Conflicts of interest

The authors declare no conflict of interest.

Financial support

None.

Institutional review board statement

This was a case based observation and was first done as a part of postgraduate teaching training while demonstrating Minimal, Low, and Conventional flow anaesthesia. Later on, it was repeated in 5 cases (with permission/informed consent from the patient). To be noted, no intervention was done in the patients. In our institute, for a case report or case series or case based review or case based clinical paper, *etc.*; institutional review board clearance is not required. Only departmental permission and consent from the patient is required, which was obtained. However, a formal study in the similar line is planned by the department and the same is already approved from the research cell and awaiting ethical clearance and CTRI registration.

Declaration of patient consent

The authors certify that they have obtained patient consent forms. In the form, patients have given their consent for their images and other clinical information to be reported in the journal. The patients understand that their names and initials not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Reporting statement

As it was not a trial and analyze data from only five cases who routinely underwent anaesthesia management and data record (with slight equipmenadaptation), the reporting followed REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) to an extent.

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Data sharing statement

Datasets analyzed during the current study are available from the corresponding author on reasonable request.

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