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Causes of Nitrous Oxide Contamination in Operating Rooms

Yuichi Kanmura, M.D.,* Junya Sakai, Ph.D.,† Heiji Yoshinaka, M.D.,‡ Kazusada Shirao, M.D.§

Background: To reduce the ambient concentration of waste anesthetic agents, exhaust gas scavenging systems are standard in almost all operating rooms. The incidence of contamination and the factors that may increase the concentrations of ambient anesthetic gases have not been evaluated fully during routine circumstances, however.

Methods: Concentrations of nitrous oxide (N_2O) in ambient air were monitored automatically in 10 operating rooms in Kagoshima University Hospital from January to March 1997. Ambient air was sampled automatically from each operating room, and the concentrations of N_2O were analyzed every 22 min by an infrared spectrophotometer. The output of the N_2O analyzer was integrated electronically regarding time, and data were displayed on a monitor in the administrative office for anesthesia supervisors. A concentration of $N_2O > 50$ parts per million was regarded as abnormally high and was displayed with an alarm signal. The cause of the high concentration of N_2O was then sought.

Results: During the 3-month investigation, N_2O was used in 402 cases. Abnormally high concentrations of N_2O were detected at some time during 104 (25.9%) of those cases. The causes were mask ventilation (42 cases, 40.4% of detected cases), unconnected scavenging systems (20 cases, 19.2%), leak around uncuffed pediatric endotracheal tube (13 cases, 12.5%), equipment leakage (12 cases, 11.5%), and others (17 cases, 16.4%).

Conclusions: N_2O contamination was common during routine circumstances in our operating rooms. An unconnected scavenging system led to the highest concentrations of N_2O recorded. Proper use of scavenging systems is necessary if contamination by anesthetic gas is to be limited. (Key words: Inhalation anesthetics; leakage; occupational exposure.)

* Associate Professor of Operating Rooms, Kyushu University Hospital, Fukuoka, Japan.

† Professor of Urban Science, Department of Human Informatics, Faculty of Urban Science, Meijo University, Gifu, Japan.

‡ Associate Professor of Operating Rooms, Kagoshima University Hospital, Kagoshima, Japan.

§ Instructor of Operating Rooms, Kagoshima University Hospital, Kagoshima, Japan.

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STRATEGIES to reduce the concentration of contaminant anesthetic gases in operating rooms are considered by many to be important, and the scavenging of anesthetic gases has become routine in operating rooms.¹ If anesthetic circuits are gas tight and conventional scavenging systems work properly, they should be capable of reducing contamination to near-zero levels. Even so, obtaining more detailed information about the incidence and causes of nitrous oxide (N_2O) contamination during routine circumstances in operating rooms and devising better ways of limiting such contamination seemed to us to be advisable, even if the health risks are still open to debate.^{2,3}

The current study was undertaken to measure the concentrations of N_2O present in our operating rooms during routine daily use and to establish the causes of any abnormally high values.

Methods

Environmental Conditions

The study was performed from January to March 1997 in Kagoshima University Hospital, which has 11 operating rooms. Among these 11 operating rooms, 1 room is a clean room for the implantation of artificial joints. Therefore, data were collected for the remaining 10 operating rooms. Approval for the study was granted by the Institutional Research Committee of Kagoshima University Hospital. The ventilation and air conditioning systems are separate from those that serve the rest of the hospital. All the operating rooms are equipped with a laminar flow system (air change rate = 20 changes/h). All the ventilated air was fresh air, and no ventilated air was recirculated. All operating rooms are equipped with the scavenging systems, which are active ones that use a venturi system powered by compressed air with open reservoirs.

Automated System for Analyzing Concentration of Nitrous Oxide

We developed an anesthetic contamination monitoring system in 1986. Using this system, we measured the con-

centration of N_2O in each of the 10 operating rooms. Operating room air was automatically sampled *via* a pneumatic system. One sampling port was present in each operating room, and it was situated at an air-conditioning exhaust grille in the wall of the operating room (30 cm above the floor and ≈ 3 m from the anesthetic machine). The air in each operating room was aspirated continuously by a sampling pump at a flow rate of 40 l/min. Twenty electrically operated valves controlled the 10 sampling lines and selected one line to be connected to the analyzing unit. The concentration of N_2O in each sample was determined by an infrared spectrophotometer (Miran 103 Analyzer; Foxboro Co., East Bridgewater, MA).

It took 90 s to change the air in the analyzing unit completely. Then, after 30 s for measurement, the average value beyond that 30 s was recorded. Thus, the sampling time for one operating room was 120 s, and data from a given operating room were collected once every 22 min.

Electronic integration of the output of the N_2O analyzer regarding time was performed using a computer system (M 343-SX; SORD, Fukuoka, Japan). Concentration of N_2O was displayed numerically in each operating room and on a monitor in the administrative office for anesthesia supervisors. The maximum concentration of N_2O recommended by the National Institute for Occupational Safety and Health is 25 parts per million (ppm; time-weighted average over the time of exposure), but in this study a spot concentration of > 50 ppm was regarded as abnormally high, and such a level triggered alarms in the operating room and on the monitor in the administrative office for anesthesia supervisors. Whenever an abnormally high concentration of N_2O was detected, the cause was sought by the supervisory staff first by inspection and then by the use of a portable Miran 103 Analyzer if the cause could not be found by inspection. After the cause was found, the error was corrected quickly. This automated sampling system was in operation from 7:00 AM until 7:00 PM on each working day, and data were collected throughout this period.

The system has been in use since 1986, and all anesthesiologists in our hospital were familiar with this system; however, we did not inform the anesthesiologists about this study before or during the period of data collection. Thus, the current study gives a picture of what actually happens in routine practice in our operating rooms.

Statistical Analysis

Concentrations of N_2O were grouped according to the causes of the contamination, and the values are ex-

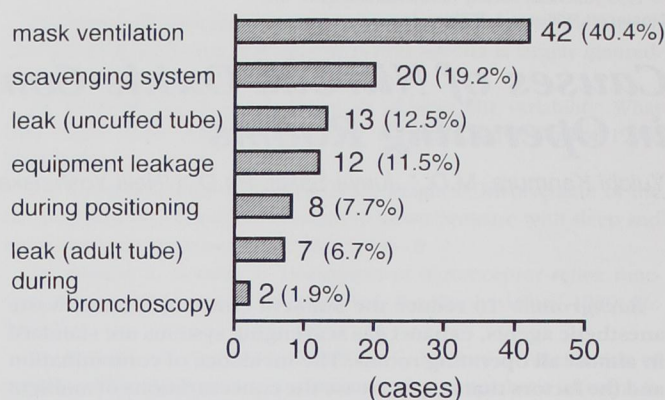


Fig. 1. Causes of increases in the concentration of N_2O in 104 cases (figures in parentheses indicate the number of cases expressed as a percentage of the cases in which an abnormally high concentration of N_2O was detected).

pressed as mean \pm SD. To test the differences between these grouped concentrations of N_2O , a one-way analysis of variance followed by a Bonferroni-corrected *t* test was used. A probability value of < 0.05 was regarded as significant.

Results

In the course of the 3-month investigation, N_2O was used for 402 cases during the observation period of 7:00 AM to 7:00 PM. Abnormally high concentrations of N_2O (> 50 ppm) were detected at least once in 104 of these cases (25.9%). Among the 103 operations involving patients < 10 yr old, a concentration of N_2O of > 50 ppm was detected in 34%.

Figure 1 shows the causes of the increased concentrations of N_2O . The most common cause was the use of mask ventilation during the induction period in adult and pediatric cases. The second cause was an unconnected scavenging system. All the operating rooms in our hospital are equipped with a waste anesthetic gas scavenging system. In these cases, however, the anesthesiologist either did not connect the suction hose to the ejector or did not open the valve that would have allowed compressed air to drive the aspiration pump (on the injector [venturi] principle). The third cause was a leak around an uncuffed pediatric endotracheal tube. The fourth cause was equipment leakage. Anesthetic gas leaked from the conduit tube leading from the ventilator to the breathing circuit in six cases. In another four cases, the leak occurred downstream from the common gas outlet (*i.e.*, carbon dioxide absorber and oxygen monitor sensor adaptor) and in another two cases from

CAUSES OF NITROUS OXIDE CONTAMINATION

Table 1. N₂O Concentrations Associated with Different Situations

Cause (number of cases)	N ₂ O (ppm)
Mask ventilation (42)	93 ± 50
Unconnected scavenging system (20)	157 ± 80*
Leak from uncuffed pediatric tube (13)	85 ± 27
Equipment leakage (12)	92 ± 50
During positioning (8)	67 ± 14
Leak from cuffed adult tube (7)	81 ± 23

Data are shown as mean ± SD.

**P* < 0.05 compared with other values.

the exhaust outlet of the capnometer. The fifth cause was a leak during the positioning of the patient, when the breathing circuit was temporarily disconnected from the endotracheal tube.

By inspection or by the use of a portable Miran 103 Analyzer, we were able to identify the causes of N₂O contamination in all the cases in which an abnormally high concentration of N₂O was detected. After the problem had been corrected, the next measurement of concentration of N₂O in that room (22 min later) gave a value within the normal range (< 50 ppm), excepting nine of the cases in which a leak from an uncuffed pediatric tube was the cause.

We investigated the distribution of the times of day at which abnormally high concentrations of N₂O were detected. In 42 cases (40.4% of detected cases), the abnormally high concentration of N₂O was detected between 8:00 and 9:00 AM, in 25 cases (24.0%) between 9:00 and 10:00 AM, in 12 cases (11.5%) between 2:00 and 3:00 PM, and in 11 cases (10.6%) between 1:00 and 2:00 PM. In the other periods, fewer than five cases were detected per hour. The peak time (between 8:00 and 10:00 AM) and the second peak time (between 1:00 and 3:00 PM) corresponded to the times at which induction of anesthesia typically took place.

The mean concentrations of N₂O during a variety of circumstances are shown in table 1. The concentration of N₂O was highest when the scavenging system was unconnected or the valve not opened, and the concentration was significantly higher when that was the cause of the problem than for any of the other causes.

Discussion

There has long been a debate regarding the health hazards of the waste anesthetic gases that may be present in the operating rooms, but this debate remains

unresolved.⁴⁻⁹ Despite the lack of concrete information in this area, the standards of the National Institute for Occupational Safety and Health call for the concentrations of ambient anesthetic gases to be monitored and limited. Currently, exhaust gas scavenging systems are standard in almost all operating rooms. We do not know, however, what actually happens in operating rooms during the course of routine practice. The current study was designed to provide such information. In our hospital, an anesthetic contamination monitoring system was installed in 1986. This system samples the atmosphere in every operation room on a regular basis and sounds an alarm whenever concentrations of N₂O exceed 50 ppm. This alarm prompts an immediate search for the source of N₂O. Such a system of constant monitoring and feedback enabled us to collect data for our operating rooms during routine circumstances. Further, it represents a near-optimal mechanism for reducing N₂O contamination.

In the current study, we found a high incidence (25.9% of cases) of N₂O contamination in our operating rooms. Our findings indicate that even though all operating room staff members knew that the monitoring and alarm system were in place, and even though the monitoring was elaborate, instances of N₂O contamination were still common. Our measuring system for N₂O did not operate continuously; instead, data were averaged over a 30-s period every 22 min. Consequently, the real incidence of N₂O pollution could be even higher than that reported here.

We also investigated the cause of the N₂O contamination in each case. Some previous reports have already dealt with the factors leading to increased ambient exposure to N₂O.¹⁰⁻¹² The current investigation was novel in that it examined the sources of contamination during routine circumstances. In our study, the causes of the contamination were similar to those detailed in previous reports,¹⁰⁻¹² and we confirmed the importance of a scavenging system in limiting cases of N₂O contamination.

The most common source of N₂O contamination was leakage from the mask during the induction period. A poorly fitting or loosely applied face mask and careless handling of anesthetic agents are the dominant factors in this type of leakage.¹³ In adult cases, the use of an intravenous technique for the induction of anesthesia would reduce anesthetic gas spillage. In pediatric anesthesia, in which we could not use an intravenous technique for induction, the double mask system may be useful in scavenging anesthetic gases escaping around face masks.^{14,15} The time distribution of the abnormally

high concentrations of N_2O could be partly explained by leakage from the mask during the induction period.

The second cause was human error. No failure of the scavenging systems occurred during the study period. In 20 cases, however, the anesthesiologist did not use the scavenging system properly, and thus the system did not work as intended. The concentration of N_2O found to result from inadequate scavenging was higher than that found with any of the other causes of contamination. Consequently, it is essential to confirm that the scavenging system is functioning normally before anesthesia is induced, and educating residents about the role of this system is important. Moreover, no type of anesthetic machine is equipped with an alarm to indicate an unconnected scavenging system. If such an alarm could be fitted to anesthetic machines, it would help to reduce the N_2O contamination in operating rooms.

The leak around an uncuffed pediatric endotracheal tube is sometimes considerable. It is difficult to manage this leak. The use of a double mask system has been proposed to reduce anesthetic contamination in this situation,¹⁴ but this idea is not popular currently. Recently, Khine *et al.* reported that, in full-term newborns and children, cuffed endotracheal tubes could be used, thus decreasing the ambient concentration of N_2O significantly.¹⁶ If no complications are involved in using a cuffed endotracheal tube, N_2O contamination could be reduced dramatically in pediatric anesthesia by this means.

The other causes detailed here (including leakage from the anesthetic apparatus) can easily escape notice without routine monitoring of the concentration of N_2O in the operating rooms. A monitoring system has been recommended to evaluate the effectiveness of anesthetic gas scavenging systems.^{17,18} Despite our elaborate monitoring and alarm system, however, we still encountered contamination by N_2O during routine practice. An even more elaborate, continuous monitoring system might be more useful, but it is not clear that such a system would be cost effective. On the basis of the results obtained in the current investigation, we think that if contamination by anesthetic gases is to be limited, it is important to recognize the likely causes of the contamination and the role of the scavenging system.

This study demonstrated that N_2O contamination is a frequent occurrence during routine circumstances in operating rooms. Among the causes, failure to use the scavenging system properly led to the highest concentrations of N_2O recorded in this study. To limit anes-

thetic gas contamination, the most important factor is proper use of scavenging systems.

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