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Operating room nitrous oxide trace concentrations: a clinical study in ambulatory surgery

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Abstract

Purpose: This blinded study evaluates the N_2O concentration variations in an ambulatory surgery centre using a small, simple on-line trace gas concentration monitor (GasFinder^{TM} [Medair AB, Delsbo, Sweden]).
Scope: Thirty-seven day surgical sessions using standardised anaesthesia with propofol/fentanyl induction and sevoflurane/N_2O with larynx mask. Five of 37 time-weighted averages (TWA) were greater than 25 ppm but less than 100. Peak registered concentrations reached 2000 ppm. Eleven sessions showed peak values higher than 100 ppm (range 13–1693).
Conclusions: This simple, on-line N_2O monitor is a useful tool for detecting deviations from strict gas hygiene.

Keywords: Ambulatory surgery; Nitrous oxide; Occupational environment and health

1. Introduction

The risks associated with chronic exposure to trace concentrations of anaesthetic gases are not established [1]. Due to potential health risks that cannot fully be foreseen, most countries have established national guidelines for safe exposure limits based on a time-weighed average (TWA) over an 8 h period. As the dose–safety relationship is not well-defined, the maximum accepted TWA value varies with country among which the United States' National Institute for Occupational Safety Health (NIOSH) is one of the more conservative and sets the limit for nitrous oxide at 25 ppm [2]. Most European countries have a 100 ppm limit for nitrous oxide.

The aim of the present investigation was to blindly monitor nitrous oxide TWA values during routine anaesthesia in an ambulatory centre with strict gas hygiene routines and fixed anaesthetic protocols. A simple, trace concentration monitor based on infrared technique was used.

2. Methods

Gasfinder^{TM} trace nitrous oxide concentration monitors (Medair AB, Delsbo, Sweden) were placed on the top-front of the anaesthetic machines in two random operating theatres for ambulatory surgery. Measurements were started at the start of the first case and continued throughout the typically 8 h day (range 6–9 h) with an average of seven cases per theatre day. The Gasfinder^{TM} is a small (125 g), commercially available, relatively simple indicator of nitrous oxide in trace concentrations. Gasfinder^{TM} uses an infrared gas sensor and sampling is done through gas diffusion. It is intended to detect both chronic and acute leaks by providing both instantaneous and cumulative TWA nitrous oxide concentrations in parts per million with an updating time of about 20 s.

All personnel were blinded, unaware of the monitoring. Anaesthesia followed departmental routines consisting of co-administration of propofol and fentanyl (20–50 mg and 0.05 mg, i.v., respectively) for sedation and anxiolysis when patients were on the operating table. Preparation, washing and dressing were done while patients were awake but sedated. Induction with propofol and fentanyl (0.05 mg, i.v.) after

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2–4 min preoxygenation with a facemask. An ordinary laryngeal mask was placed immediately after induction without prior ventilation with inhaled anaesthetics. When the laryngeal mask was in place and tightened, a fresh gas flow of 1 L/min oxygen, 2 L/min nitrous oxide and sevoflurane 1–2% (dialled) was initiated with assisted ventilation until spontaneous breathing resumed. Semi-closed anaesthetic circuits were used, and sevoflurane was titrated according to clinical needs. No muscle relaxants were used. At the end of surgery all anaesthetic gases were turned off and fresh gas flow was resumed (oxygen 6 L/min and 2–3 L/min air). The laryngeal mask was not removed until patients were so awake they showed discomfort from the mask. All operating theatres have an ordinary climate ventilation system (approximately 25 changes/h) and all anaesthetic machines are connected to a standard scavenging system (−20 cm H_2O or about 5 L/min).

3. Statistics

Nitrous oxide concentrations are given as average and range.

4. Results

Thirty-seven ambulatory surgery sessions (approximately 8 h days) were monitored. Five TWAs were above the NIOSH limit of 25 ppm (26, 40, 58, 79 and 85 ppm, respectively). In 11 recordings, peak levels were above 100 ppm and 3 were above 500 ppm. The mean TWA for all 37 recordings was below 25 ppm (range 1–85 ppm). Figs. 1–3 show nitrous oxide concentrations for a session using laryngeal mask per department routine, another where an anaesthetic mask was used instead of larynx mask, and one for an operating theatre when the exhaust suction was accidentally forgotten.

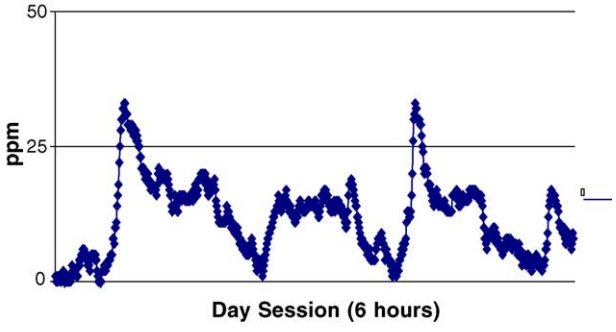

Fig. 1. Nitrous oxide concentration (ppm) vs. session time for a session using laryngeal mask per department routine.

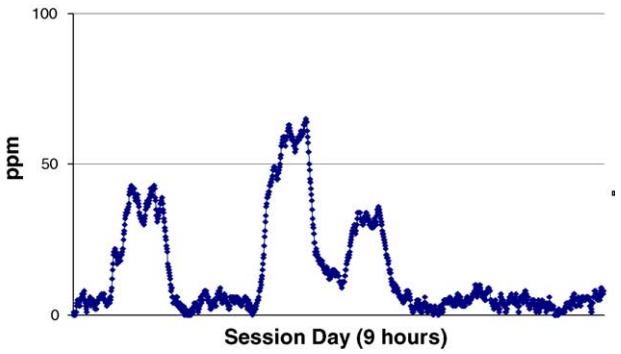

Fig. 2. Nitrous oxide concentration (ppm) vs. session time for a surgical theatre day when facemask was used.

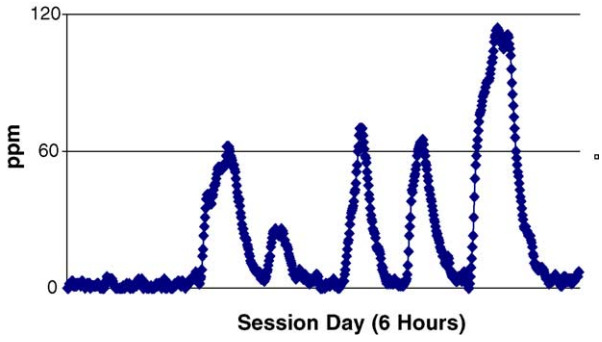

Fig. 3. Nitrous oxide concentration (ppm) vs. session time for a surgical theatre day when exhaust system was forgotten.

5. Discussion

This study investigated workplace nitrous oxide exposure in the surgical theatre using a simple, on-line trace gas concentration monitor. In the type of ambulatory surgery theatres studied where proactive gas hygiene anaesthetic techniques and equipment are used, the day averages of nitrous oxide concentrations were generally reassuringly low. Incidents with unnecessarily high peak and daylong averages of nitrous oxide concentrations were observed. This study indicates the potential value of a simple on-line monitor or dosimeter of the ambient air nitrous oxide trace concentration to reassure adequate work place air quality even when a stringent anaesthetic technique is used.

Long-term occupational exposure to trace concentrations of volatile anaesthetics has been considered to have adverse health effects on the exposed personnel [3,4]. Both halogenated inhaled anaesthetics and nitrous oxide have been associated with potential negative health effects [5,6]. Whether these potential health hazards are associated with environmental trace concentrations of nitrous oxide, halogenated inhaled anaesthetics or a combination of factors is not fully established [3,7].

Even on the basis of present knowledge a reduction of work exposure levels of nitrous oxide to the lowest possible levels is motivated by the well-described inactivation of methionine synthase from experimental studies with nitrous

oxide and secondarily the potential change in production of DNA precursors [8,9]. Experimental studies use higher nitrous oxide concentrations than occur typically in hospital environments, but the clinical implication of impaired methionine turnover is also well-known with potential effects on bone marrow and neurological symptoms [3]. The potential negative effects from more extensive chronic exposure to trace concentrations such as spontaneous abortions and impaired fertility have been shown in dental assistants [10]. Unfortunately, specific concentrations or amount of exposure were not determined in that study. The exact safe level is difficult to define, if indeed there is a threshold value, and it may vary with other factors such as Vitamin B12 and folate status. This range of uncertainty is reflected by the range of national limits: Most European health authorities have a TWA nitrous oxide limit of 100 ppm while in the USA the NIOSH has set a more conservative level of 25 ppm [2].

This study has shown that the more conservative limit of 25 ppm is generally not difficult to achieve if optimal anaesthetic techniques are used. The vast majority of measurements in the present study were well below the NIOSH limit of 25 ppm but during a handful of sessions TWA values above 25 ppm were recorded, indicating that inattention to stringent anaesthetic practice will result in unacceptably high levels. A number of peak readings were clearly higher than recommended levels. The blinding of the measurements prevented identifying the cause of TWA readings higher than 25 ppm in most cases. On one occasion, however, one of the investigators noticed gas leakage during a session when an ordinary mask was used instead of the clinical routine with laryngeal mask. In another case the gas exhaust system had not been turned on. As baseline instantaneous concentrations are low in this study, increased TWA values can be concluded to arise from personnel errors and not background leakage. These errors are most likely to occur at the beginning and end of each case.

Both economic and health considerations have resulted in a modern anaesthetic practice which generally employs closed circle systems with minimal gas leakage and waste scavengers attached to all anaesthetic machines. Forced ventilation in operating theatres, principally for infection prevention, further promotes low anaesthetic gas trace concentrations in the surrounding air. All these technical improvements may not be potent enough to guarantee acceptable workplace environments if guidelines for gas and equipment use are not followed.

The present study corroborates the reassuring results observed in other recent studies on operating room concentrations of anaesthetics [11,12]. There are, however, papers showing that nitrous oxide exposure is still a problem [13]. The results presented here must be interpreted in the context of an ambulatory centre which consistently employs anaesthetic protocols, a semi-closed anaesthetic circuit and equipment associated with optimal gas hygiene. The use of intravenous induction, lack of muscle relaxants, and not starting the use of inhaled anaesthetics until a laryngeal mask airway is in place and tightened has been shown to minimize environmental gas concentrations [14,15]. Higher concentrations have been found repeatedly during mask induction and ventilation [13,16]. Even the technique used during emergence has an impact [17]. Finally, not only ventilation technique but also accidentally de-activated scavenging systems and leaking anaesthetic equipment have been shown to contribute to high operating room nitrous oxide concentrations [16,17].

Some may argue that nitrous oxide is no longer appropriate for ambulatory anaesthesia [18]. The use of nitrous oxide has, however, been shown to promote spontaneous breathing, improve emergence, shorten the time to resumption of spontaneous breathing, time to extubation or removal of the laryngeal mask as well as time to orientation [19–21]. Nitrous oxide has been shown to be cost-effective in day surgery [22].

This study employed a simple gas detector that makes continuous nitrous oxide trace monitoring available to normal anaesthetic units. The technique used in the Gasfinder™ is simplified by depending on gas diffusion and detection using infrared technique. Ambient gas is not actively brought into the device. Its calibration guarantees to indicate when nitrous oxide levels are lower than the lowest accepted limits (25 ppm), but it does not give the exact values at those low concentrations. The accuracy for the Gasfinder™ has been confirmed for concentrations 100 ppm, 300 ppm and 1000 ppm.

In summary, during routine ambulatory anaesthesia with intravenous induction and spontaneous breathing with a laryngeal mask inhaled anaesthetic maintenance, trace concentrations of nitrous oxide are generally not a major concern. Surgical sessions with unnecessarily high nitrous oxide concentrations do occur, however, even in centres with stringent anaesthetic techniques. The Gasfinder™, measuring real-time nitrous oxide concentrations in ambient air, has an educational effect and could help to maintain a high degree of awareness for optimal gas hygiene in addition to detecting other technical errors.

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