

## Environmental monitoring during gaseous induction with sevoflurane

J. E. HALL, K. A. HENDERSON, T. A. OLDHAM, S. PUGH AND M. HARMER

### Summary

Recent research has shown that gaseous induction in adults with sevoflurane is an acceptable technique. This study was undertaken to assess if gaseous induction using sevoflurane carried in both oxygen alone, and in nitrous oxide and oxygen combined, would provide acceptable pollution levels. As an occupational exposure standard has not been set for sevoflurane, we used the target level of 20 ppm set by the manufacturer. Environmental monitoring was carried out in the anaesthetic room during eight lists where consecutive triple vital capacity sevoflurane inductions were performed. Time-weighted averages for both gases over the duration of the lists were well below the occupational exposure standards (mean 1.1 (range 0.6–1.7) for sevoflurane and 17.3 (12–23) for nitrous oxide). There were high peak concentrations during the induction process (8.3 (4.1–17) for sevoflurane and 172.4 (65–310) for nitrous oxide) although these decreased to low concentrations between anaesthetic inductions. Personal sampling was carried out from the anaesthetist's breathing zone and concentrations were also low (1.2 (0.8–2.1) for sevoflurane and 45.9 (10.1–261.6) for nitrous oxide. (*Br. J. Anaesth.* 1997; **79**: 342–345).

### Key words

Anaesthetics volatile, sevoflurane. Operating rooms, contamination.

Gaseous induction of anaesthesia is possible with sevoflurane in adults because of its low blood-gas solubility and non-irritant nature.<sup>1</sup> Several studies have demonstrated rapid induction of anaesthesia with high concentrations of the gas. Both tidal volume<sup>2</sup> and vital capacity<sup>3</sup> inductions have been tried successfully at high concentration with perhaps the latter technique being slightly faster and smoother. Gaseous induction with sevoflurane appears to be safe in patients for induction, but the effect on pollution levels in the anaesthetic room is not known.

This study was undertaken to determine pollution levels in the anaesthetic room concomitant with high concentration, triple vital capacity induction in adults using sevoflurane. An occupational exposure level of 20 ppm has been set by the manufacturers of sevoflurane. During three lists, nitrous oxide was monitored to assess the

acceptability of using this agent in the fresh gas flow during induction.

### Materials and methods

Environmental pollution was studied during eight consecutive orthopaedic lists where a relatively high turnover of patients was expected. Sevoflurane was monitored during five lists when there were 23 inductions, while nitrous oxide was monitored during three lists when there were 12 inductions. There were six personal samples obtained measuring sevoflurane concentrations and nine measuring nitrous oxide concentrations. Monitoring was performed in the anaesthetic room and all breathing systems were subject to active scavenging by a Venturi injector system operated by an 8 litre min<sup>-1</sup> oxygen source on the anaesthetic machine. Consecutive gaseous inductions were performed with no i.v. inductions. Sevoflurane and nitrous oxide were used for maintenance of anaesthesia in theatre so that inadvertent spillage of anaesthetic gases could be monitored as this might affect background pollution levels.

Two methods of environmental monitoring were used, background sampling and personal sampling.

### BACKGROUND ENVIRONMENTAL SAMPLING

Environmental pollution associated with the use of a Bain breathing system (co-axial Mapleson D) was examined. All inductions were performed in one of two anaesthetic rooms and air changes were measured formally in these rooms using sulphur hexafluoride and an infrared spectrometer. Twenty-five inductions were carried out in one anaesthetic room and 10 in the other.

Environmental monitoring of the anaesthetic gases was performed using a MIRAN 1B. This is a portable ambient air analyser which uses a single beam infrared spectrophotometer to measure background air pollution in working environments. Nitrous oxide was sampled at a wavelength of 4.68  $\mu\text{m}$  and sevoflurane at 8.9  $\mu\text{m}$ . The MIRAN was calibrated using the MIRAN closed-loop calibration

J. E. HALL, MA, FRCA, T. A. OLDHAM, FRCA, S. PUGH, FRCA, M. HARMER, FRCA (Department of Anaesthetics and Intensive Care Medicine); K. A. HENDERSON, BSC (Health and Safety Department); University of Wales College of Medicine, Heath Park, Cardiff CF4 4XN. Accepted for publication: April 8, 1997.

Correspondence to J. E. H.

system before starting the study by introducing a known volume of anaesthetic agent into the MIRAN.

The MIRAN probe was positioned between 80 and 120 cm from the patient's head, behind and slightly to one side of the anaesthetist in an attempt to sample the highest concentrations of volatile agent. Monitoring was carried out for the whole theatre list to obtain a picture of the peaks and troughs throughout the day. Data were transferred onto a data logger and this information was then converted to graphical form.

The following gaseous induction techniques were used.

#### *Sevoflurane monitoring*

After preoxygenation, the patient was instructed to take a deep inspiration of 100% oxygen, and during the subsequent expiration, the inspired gas composition was changed to the induction mixture of 8% (dial) in oxygen. Induction then commenced with the patient taking three consecutive vital capacity breaths, the third breath being held for as long as possible. When patients were unable to hold this breath any longer, they were allowed to breathe normally. Patients were instructed in the induction technique before operation. Initially fresh gas flows of 9 litre min<sup>-1</sup> were used, which were reduced to 6 litre min<sup>-1</sup> after loss of consciousness. The high gas flow technique ensured a rapid increase in the inspired concentration of sevoflurane necessary for rapid induction. The time taken for the inspired concentration of sevoflurane to increase to greater than 7% was approximately 5–6 s. Inspired gas concentrations were measured using a Capnomac Ultima monitor (Datex, Helsinki, Finland) via a sampling cannula placed between the distal end of the breathing system and the face mask. Jaw relaxation was tested every 30 s after loss of consciousness and a laryngeal mask airway was inserted when this was achieved. During insertion of the laryngeal mask airway, the breathing system was placed on the pillow next to the patient's head with the fresh gas flow still running; 23 inductions were carried out using this technique.

#### *Nitrous oxide monitoring*

In inductions where nitrous oxide was monitored, the induction technique was as described above, except that the induction mixture, when commenced, was 8% sevoflurane carried in nitrous oxide and oxygen (ratio 2:1); 12 inductions were carried out using this technique.

Gaseous inductions were carried out by two of the

authors (J. E. H. and S. P.). Both anaesthetists were familiar with the triple vital capacity breath induction technique.

#### PERSONAL SAMPLING

This was carried out using a 1-litre gas reservoir connected to a personal sampling pump. It was attached to the anaesthetist and sampled air directly from the breathing zone. Sampling was carried out over 1 h during which time one or two gaseous inductions were performed to give a single result. The gas sample was then analysed using the MIRAN 1B. Exposure of the anaesthetist during the hour of sampling was calculated taking into account the volume of the personal sampling system.

#### Results

Air changes in both anaesthetic rooms were within acceptable limits,<sup>4</sup> one room having 15 changes per hour (where 10 inductions were carried out) and the other 17 air changes per hour (where 25 inductions were carried out).

#### BACKGROUND EXPOSURE

Background exposures were low when assessed as time-weighted averages (TWA) (table 1). Conventionally it is usual to express TWA over an 8-h period but the operating lists were not so prolonged, and values were averaged over the period of each list. Peaks of both sevoflurane and nitrous oxide during induction of anaesthesia were followed rapidly by low background concentrations. All peaks for sevoflurane were less than 20 ppm and most were less than 10 ppm. Occasional higher results could be explained by an incident during anaesthesia (for example during induction with a sevoflurane peak of 17 ppm, the size 4 laryngeal mask airway was removed and replaced by a size 5 airway causing some extra pollution). There was more variability in the peak values for nitrous oxide, although TWA values were also below the occupational exposure standard (OES).

#### PERSONAL EXPOSURE

Personal sampling during induction and maintenance of anaesthesia revealed low exposure. One nitrous oxide personal sample appeared to be unusually high (261 ppm). This bag was removed at one point from the anaesthetist while still sampling and placed on the anaesthetic machine. It is possible that it came into contact with concentrated nitrous oxide during a circuit break at this time.

Table 1 Peak, personal reservoir sample and time weighted average gaseous concentrations (mean (range))

	Peak levels (ppm)	Time weighted average (ppm)	Personal reservoir sample concentration (ppm)
Sevoflurane (5 lists, 23 inductions, 6 personal samples)	8.3 (4.1–17.0)	1.1 (0.6–1.7)	1.2 (0.8–2.1)
Nitrous oxide (3 lists, 12 inductions, 9 personal samples)	172.4 (65–310)	17.3 (12.23)	45.9 (10.1–261.6)

## Discussion

While there is at present no official OES for sevoflurane, it is a halogenated ether, similar to enflurane and isoflurane, both of which have an OES of 50 ppm.<sup>5</sup> Target compliance with this level is probably sensible. Abbott Laboratories, the manufacturers of sevoflurane, have suggested a limit of 20 ppm.<sup>6</sup> This was set to be 100 times lower than the level which would have any clinical effect (i.e. 2000 ppm). These two limits have been chosen arbitrarily, but the 20 ppm limit is conservative compared with levels for isoflurane and enflurane, although the OES for halothane is 10 ppm. With the 20 ppm limit in mind it seems that high concentration sevoflurane induction in adults complies with the environmental standard. Monitoring was also carried out during gaseous induction with sevoflurane carried in combined nitrous oxide and oxygen. The OES for nitrous oxide is 100 ppm, and the TWA complied with this.

Using the personal sampling apparatus, samples were obtained directly from the breathing zone of the anaesthetist to provide a clearer picture of personal exposure. More marked increases in volatile concentration could have been expected, but this was not manifest and the anaesthetists received low exposures. There was one high result among the nitrous oxide samples which may have been caused by intraoperative breathing system disconnection.

The Mapleson A breathing system was used in an early gaseous induction study<sup>7</sup> and has been used subsequently<sup>8</sup> but it is probably not the best system for the vital capacity technique because of the need to prefill the breathing system. This necessitates changing from a separate preoxygenation system, probably causing environmental spillage. In addition, the technique is quite cumbersome, extra equipment is needed in theatre and the stopper on the system may dislodge causing further pollution. The use of high fresh gas flows with the Bain allows induction to be carried out with a single breathing system. The Bain can be used conveniently for gaseous induction without necessitating changing the system after preoxygenation. It was decided not to examine pollution associated with the circle system because this is used infrequently in the anaesthetic room in our own practice. Gaseous induction with a circle system would probably be economical to use and associated with low pollution, if anaesthesia was induced in theatre. The circle system has been used for halothane gaseous induction<sup>9</sup> and environmental monitoring would be of interest to hospitals using this breathing system for induction and in countries which do not use anaesthetic rooms.

The marked influence of individual anaesthetists on levels of environmental pollution has been demonstrated by Gray and Spence<sup>10</sup> who found that the anaesthetist's exposure varied by a factor of 17 on a day-to-day basis. The influence of different techniques cannot be underestimated and our highest sevoflurane peak was associated with change of a laryngeal mask airway. The anaesthetics in this study were conducted by two different anaesthetists

who, although both familiar with the triple vital capacity gaseous induction technique, would inevitably use slightly different anaesthetic techniques. This variation aside, using the prescribed method, neither anaesthetist produced pollution of such levels that the OES values were contravened.

Anaesthetists are exposed constantly to low levels of volatile anaesthetic agents. Early epidemiological research which examined occupational health exposure was often poorly controlled. A large body of research has examined the biological effect of chronic exposure on animals. Work in rats has shown nitrous oxide to be associated with a lower implantation rate and a higher fetal death rate.<sup>11</sup> In addition, production of smaller rat litters and increased skeletal malformation have also been demonstrated.<sup>12</sup> Volatile agents have also been implicated in animal work with skeletal anomalies being demonstrated after 12-h exposure to 0.8% halothane in rats.<sup>13</sup> Extrapolation to humans is of course difficult, but by the late 1980s there was a sufficient body of evidence to negate the association between human developmental toxicity and nitrous oxide.<sup>14</sup> A 10-yr prospective study was undertaken by Spence,<sup>15</sup> the results of which have been partially reported to the Medical Research Council. Initial results would seem to suggest that anaesthesia is not associated with an occupational health risk.

The OES were set by the Health and Safety Executive to be well below the levels thought safe for animals. There may be little convincing evidence to show an association between low anaesthetic exposure and toxicity, but high levels do have an effect and it is sensible to maintain a low level of occupational exposure to any potentially toxic substance. The 1994 regulations of the control of substances hazardous to health and the occupational exposure standards for the four named anaesthetic agents have been enforced since January 1996 in an attempt to control the anaesthetist's working environment. It appears that gaseous induction with sevoflurane with or without nitrous oxide administered by the technique we have described complies with environmental standards and lack of compliance is not a bar to the potential of sevoflurane as a single agent anaesthetic.

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