Isoflurane waste gas exposure during general anaesthesia: the laryngeal mask compared with tracheal intubation

K. H. HOERAUF, C. KOLLER, W. JAKOB, K. TAEGER AND J. HOBBHAHN

Summary
We have compared exposure to isoflurane while using the laryngeal mask airway (LMA) during anaesthesia under positive pressure ventilation with exposure while using tracheal intubation. Trace concentrations of isoflurane were measured directly using a highly sensitive photoacoustic infrared spectrometer (Bruel and Kjaer 1302, Denmark) during general anaesthesia in 20 eye surgery procedures. Measurements were made at six locations (three personnel-related, three leakage-related) in the operating theatre. Despite some high isoflurane values (greater than 2000 ppm at one leakage-related measurement point) all measured values at the personnel-related points were low (the majority were less than isoflurane 2 ppm). In the LMA group, mean trace concentrations were slightly higher than in the tracheal tube (ET) group. Mean exposure to isoflurane, expressed as median (range) related to anaesthetic administration, was highest for the auxiliary nurse (0.64 (0.22–26.89) ppm for the LMA compared with 0.31 (0.02–1.07) ppm for the tracheal tube), followed by the anaesthetist (0.50 (0.28–2.28) ppm for the LMA compared with 0.35 (0.02–0.73) ppm for the tracheal tube) and the surgeon (0.36 (0.20–3.93) ppm for the LMA compared with 0.29 (0.01–0.50) ppm for the tracheal tube). We conclude that the use of the LMA in patients undergoing ventilation is not associated necessarily with high concentrations of isoflurane in a modern working environment (Br. J. Anaesth. 1996; 77: 189–193)

Key words

American and most European public health authorities recommend threshold values (table 1) for occupational exposure to trace concentrations of volatile anaesthetic agents. The National Institute for Occupational Safety and Health (NIOSH) recommends that occupational exposure to halogenated anaesthetic agents, when used as the sole anaesthetic, should not exceed 2 ppm, expressed as time-weighted averages (TWA) [1]. In European countries, recommended threshold values for these agents range from 2 to 20 ppm. Most of the national exposure standards are related to an 8-h TWA, although the NIOSH values relate to TWA over the period of anaesthetic administration.

The laryngeal mask airway (LMA) is a relatively new device for management of the airway during general anaesthesia [2]. Brain and colleagues stated that the LMA was gas-tight in positive pressure ventilation up to 30 cm H2O [3]. A recent study has shown mean leak values of up to 27% of the inspired volume during LMA use and up to 4% during tracheal intubation, both under positive pressure ventilation (IPPV) [4]. Such high leakage during laryngeal mask anaesthesia could result in pollution of the operating theatre.

To date, data on occupational exposure of operating theatre personnel to theatre pollution during LMA anaesthesia have been available only for nitrous oxide. Lambert-Jensen, Christensen and Brynnum reported nitrous oxide exposure, comparing spontaneous and controlled ventilation using the LMA [5], and Sarma and Leman reported low nitrous oxide concentrations during spontaneous breathing [6].

In this study we measured exposure to isoflurane while using the LMA during anaesthesia with IPPV in an operating theatre with air conditioning and scavenging systems conforming to NIOSH recommendations, and compared these concentrations with exposure while using tracheal intubation under identical conditions. In contrast with earlier studies, staff exposure (surgeon, anaesthetist and auxiliary nurse) was recorded directly at the subject’s mouth, and three static points (operation area, mouth of the patient and reservoir bag of the anaesthesia machine) related to potential leakage sources were also measured.

Methods and materials
STUDY POPULATION
We studied 20 patients undergoing ophthalmological procedures under general anaesthesia in a prospective, randomized study. The treatment assignments (tracheal tube or LMA) were contained in sequen-
tially ordered sealed envelopes, which were opened before induction of anaesthesia. Ten patients received an LMA (group 1) and 10 patients a tracheal tube (ET group 2). The study did not influence routine patient management. Induction, maintenance and emergence from anaesthesia were performed in the operating theatre. Anaesthesia was induced with propofol 1.5–3.0 mg kg\(^{-1}\) (until loss of eyelash reflex) and maintained with i.v. alfentanil and isoflurane, and 65 % air in oxygen. Administration of isoflurane as the sole volatile anaesthetic agent was started after insertion of either the LMA or tracheal tube. A size 4 laryngeal mask was inserted by one of two anaesthetists using the technique recommended by the manufacturer. Tracheal RAE tubes (Mallinckrodt Medical, Germany) with an internal diameter of 7.5 mm or 7.0 mm were used for male and female patients, respectively. Fresh gas flow was 4 litre min\(^{-1}\). A new low-leakage [7] Sulla 808 V (Dräger, Germany) was used as the anaesthesia machine. Inspiratory isoflurane concentration and ventilation pressures were recorded using a Capnomac infrared analyser (Datex, Finland). The waste gas outlets of both the anaesthesia machine and the infrared analyser were connected to the central scavenging system (60 litre min\(^{-1}\) of the hospital).

WORKPLACE DESCRIPTION

The air volume of the operating theatre in this study was 130 m\(^3\). Ventilation and air conditioning systems were separate from those serving other rooms of the hospital. Connections between the recovery room, other operating theatres and the operating theatre of the study did not exist. Air conditioning was performed by a laminar flow system producing an air change rate of 20 changes per hour (2600 m\(^3\) h\(^{-1}\)) without recirculation. The location of the area below the air conditioning vents is shown in figure 1.

SAMPLING STRATEGY

Trace concentrations of isoflurane were measured directly using a highly sensitive photoacoustic infrared spectrometer (Brüel and Kjær 1302, Denmark). The lower detection limit for isoflurane was 0.009 ppm and accuracy was within \(\pm 2\%\) of the measured value. Gas was sampled under ambient pressure conditions using 8-m lengths of polyamide tubes (Siegle, Germany). Air samples were obtained sequentially at six locations (fig. 1) in the operating theatre using a Brüel and Kjær 1303 multipoint sampler. Three measurement points were personnel-related: AN = anaesthetist, S = surgeon, AX = auxiliary nurse. Sampling tubes were fitted at the operating theatre personnel’s masks, and therefore air sampling was accomplished within the breathing zone. The other three sampling points were at the sites of potential leaks: OP = operation area, M = mouth of the patient, AM = reservoir bag of the anaesthesia machine. Data from the infrared spectrometer were recorded continuously using a personal computer system. Cuff pressure in the ET group was kept within the range of 20–30 cm H\(_2\)O using an Endotest (Ruesch, Germany) manometer.

MATHEMATICS

To calculate mean exposure during administration of anaesthetic, concentrations were calculated for each anaesthetic from the area under the curves derived from intermittent measurements. These mean trace concentrations for each anaesthetic and all locations are plotted in figure 2. Median and range were calculated for each location and group and presented in table 3. Between-locations and between-group comparisons were performed using the Wilcoxon test (\(P < 0.05\)).
Results

Both anaesthetists were experienced in inducing and maintaining general anaesthesia using the LMA or tracheal tube. The masks were introduced successfully on the first or second attempt.

Mean values for exposure time during anaesthesia, ventilation pressures, inspiratory isoflurane concentration and patient data were comparable in both groups (table 2). Median and ranges of mean trace concentrations of isoflurane in both groups are shown in table 3. Distributions of mean trace concentrations of the individual anaesthetic procedures are illustrated in figure 2.

In the ET group, all personnel-related mean trace concentrations were less than isoflurane 2 ppm. In the LMA group at the locations of both the anaesthetist and the surgeon, one of 10 means exceeded this value. In the position occupied by the auxiliary nurse, three of 10 values exceeded 2 ppm. These higher values occurred during anaesthetic procedures in which values greater than isoflurane 100 ppm at the patient’s mouth were measured. Any statistically significant differences in mean trace concentrations within the personnel-related measurement points and between the ET and LMA group were detected (P < 0.05).

Leakage-related values indicated that the artificial airway was the main leakage source in both groups. Trace concentrations were higher and variation was greater in the LMA group than in the ET group. The difference between the concentrations was statistically significant between the ET and LMA groups, and within the leakage-related LMA values at point M. Trace concentrations at locations AM and OP were comparable between the groups and within the leakage-related values.

Discussion

Some studies suggest that chronic exposure to trace concentrations of volatile anaesthetics may result in various forms of untoward health responses [8, 9]. The limitations of epidemiological studies have been discussed [10, 11]. Because of flaws in the epidemiological investigations and a lack of data concerning dose relationships, it has not been possible to establish an aetiological connection between such untoward health responses and waste anaesthetic gases [12].

To maintain low occupational exposure, NIOSH has also outlined a number of criteria for the workplace [1]. These criteria were fulfilled in this study. (1) The anaesthesia machine was connected to a central high-flow scavenging system (60 litre min⁻¹). (2) Leakage from the breathing system of a typical Draeger Sulla 808V was 22.8 ml min⁻¹ [7].

Table 2 Patients data (mean (sd) or number)

<table>
<thead>
<tr>
<th>Location</th>
<th>LMA group (n = 10)</th>
<th>ET group (n = 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration of anaesthesia (min)</td>
<td>72 (34)</td>
<td>79 (24)</td>
</tr>
<tr>
<td>Surgical procedure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cataract</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>Vitrectomy</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Cerclage</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Sex (M/F)</td>
<td>7/3</td>
<td>6/4</td>
</tr>
<tr>
<td>Ventilation pressures (cm H2O)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PEEP</td>
<td>4.1 (1.1)</td>
<td>4.2 (1.2)</td>
</tr>
<tr>
<td>Plateau</td>
<td>15.8 (2.4)</td>
<td>15.7 (3.5)</td>
</tr>
<tr>
<td>Peak</td>
<td>21.8 (2.8)</td>
<td>22.4 (4.9)</td>
</tr>
<tr>
<td>Inspiratory isoflurane concentration (vol %)</td>
<td>1.21 (0.25)</td>
<td>1.16 (0.24)</td>
</tr>
</tbody>
</table>

Table 3 Median (range) mean trace concentrations related to the time over the duration of anaesthetic administration at the different measurement points in the operating theatre. Values are in parts per million (ppm). Significant differences (P < 0.05): * within leakage-related values; † between groups

<table>
<thead>
<tr>
<th>Location</th>
<th>LMA group</th>
<th>ET group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personnel-related values</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anaesthetist (AN)</td>
<td>0.50 (0.28–2.28)</td>
<td>0.35 (0.02–0.73)</td>
</tr>
<tr>
<td>Surgeon (S)</td>
<td>0.36 (0.20–3.93)</td>
<td>0.29 (0.01–0.50)</td>
</tr>
<tr>
<td>Auxiliary nurse (AX)</td>
<td>0.64 (0.22–26.89)</td>
<td>0.31 (0.02–1.07)</td>
</tr>
<tr>
<td>Leakey-related values</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating area (OP)</td>
<td>2.54 (0.22–31.02)</td>
<td>0.32 (0.06–0.76)</td>
</tr>
<tr>
<td>Patient’s mouth (M)</td>
<td>32.81 (0.46–2150)*†</td>
<td>0.89 (0.32–11.42)</td>
</tr>
<tr>
<td>Anaesthesia machine (AM)</td>
<td>0.37 (0.26–3.36)</td>
<td>0.30 (0.05–0.92)</td>
</tr>
</tbody>
</table>

Figure 2 Distribution of mean trace concentrations of isoflurane at different locations (AN = anaesthetist, S = surgeon, AX = auxiliary nurse, OP = operating area, M = mouth of patient, AM = anaesthesia machine) in the LMA and ET groups.
far below the leakage value of 150 ml min\(^{-1}\) proposed by the Draft European Standard Anaesthetic Workstations and Their Modules. (3) Anaesthetic gas flow was started after insertion of the artificial airway (LMA or tracheal tube). Intermittent face mask ventilation with isoflurane was not performed. (4) Room ventilation comprised 20 changes per hour, with no air being recirculated. (5) The waste gas outlet of the anaesthetic gas monitor, a potential source of contamination [13], was connected to the hospital’s central scavenging system (60 litre min\(^{-1}\)).

Trace concentrations of anaesthetics may be measured either off-line by gas chromatography or on-line using direct reading instruments. The system used in this study has some advantages over other direct reading instruments such as the MIRAN series. Using photoacoustic infrared spectrometry, detection levels are lower and accuracy is greater because of the possibility of cross-compensation for other gaseous substances present in the operating theatre. The Bruel and Kjaer 1302 photoacoustic infrared spectrometry system allows detection limits as low as isoflurane 0.009 ppm, with an accuracy of ±2 % [14, 15].

Mean trace concentrations were calculated for each anaesthetic from the area under the curves derived from the intermittent measurements made by the measurement system, reflecting exposure during the period of anaesthetic administration neglecting, for example, intervals between operations. We believe this method may reflect accurately occupational exposure during anaesthesia; on the other hand, corrections to an 8-h working day can be performed easily or could be adapted to individual working shift conditions.

Leakage from the artificial airway appeared to be the main source of occupational exposure. In the LMA group, 60 % of the mean values measured near the patient’s mouths were greater than isoflurane 10 ppm. Peak concentrations exceeding 100 ppm were recorded in some cases, but there was no relation to higher ventilatory pressures in these cases. In the ET group, in one patient, isoflurane mean values exceeded 10 ppm. Variation of the mean values was less for the ET group than for the LMA group.

Trace concentrations recorded at the reservoir bag of the anaesthesia machine were all less than 5 ppm, which is consistent with the reportedly low leakage rate from the breathing system of this machine [7].

As expected with this type of surgery (eye surgery), because of the proximity of the measurement point “OP” to the main leakage source, point “M”, mean values recorded at point “OP” probably do not reflect a specific contribution to air contamination.

Despite the high trace concentrations near the patient’s mouth, most personnel-related mean trace concentrations were less than the strict NIOSH limit of 2 ppm of isoflurane. Higher mean trace concentrations (three of 10) at the position of the auxiliary nurse occurred during anaesthetic procedures in the LMA group in which substantial leakage from the patient’s mouth was detected. In these patients, at the locations of both the anaesthetist and the surgeon, only one of 10 mean values exceeded 2 ppm. The higher levels for the auxiliary nurse could be explained by the position outside the main airflow of the air conditioning system and air movement from the laminar air flow field to the air exhausts in the corners of the operating theatre (fig. 1). The workplaces of the surgeon and anaesthetist, however, were within the main air flow, which probably explains why their mean concentrations were mainly less than 2 ppm in both groups.

With tracheal intubation, values of isoflurane in our study were less than those of other studies, which have reported concentrations of isoflurane 2.4–12 ppm [16], 3–11 ppm [17] and 13.4–21.0 ppm [18]. The higher values in these studies may be a result of less effective air conditioning systems, lack of a scavenging system or higher leakage from the anaesthesia machines [16–18].

Until now occupational exposure during general anaesthesia using the LMA has been measured only for nitrous oxide. Lambert-Jensen, Christensen and Brynnum found a higher, but non-significant difference in trace concentrations with controlled ventilation compared with spontaneous breathing. Nitrous oxide concentrations were 7.0–24.0 ppm under controlled ventilation and 7.5–18.4 ppm during spontaneous breathing [5]. Sarma and Leman reported that the LMA resulted in minimal theatre pollution during spontaneous ventilation. Nitrous oxide peak level ranged from 15 to 37 ppm [6].

A previous study on tracheal intubation and nitrous oxide pollution performed under identical working place conditions showed median trace concentrations at the personnel-related measurement points of 11.4–19.6 ppm [19].

We conclude that anaesthesia using the LMA in patients undergoing ventilation may be associated with high concentrations of isoflurane near the patient’s mouth because of higher leakage rates. Using an effective high-flow scavenging system and air conditioning equipment that provided 20 changes of air per hour without recirculation, and a low-leakage anaesthesia machine, mean trace concentrations in the working environment may be almost as low as those associated with anaesthesia using tracheal intubation. Under other circumstances (e.g. lower air change rates), trace concentrations of isoflurane may be higher.

**References**


