Recovery after anaesthesia for pulmonary surgery: desflurane, sevoflurane and isoflurane

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We have studied maintenance and recovery profiles after general anaesthesia with sevoflurane, desflurane and isoflurane in 100 patients undergoing pulmonary surgery. End-tidal concentrations of anaesthetic required to maintain mean arterial pressure and heart rate within 20% of baseline values were 1.4±0.6% for sevoflurane, 3.4±0.9% for desflurane and 0.7±0.3% for isoflurane. The three anaesthetics had comparable haemodynamic effects and arterial oxygenation during one-lung ventilation. Emergence was twice as fast with desflurane than with sevoflurane or isoflurane (mean times to extubation: 8.9 (±5.0) min, 18.0 (17.0) min and 16.2 (11.0) min for desflurane, sevoflurane and isoflurane, respectively). Early recovery (Aldrete score, cognitive and psychomotor functions) was also more rapid after desflurane. In pulmonary surgery, desflurane, but not sevoflurane, allowed more rapid emergence and earlier recovery than isoflurane.

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In pulmonary surgery, inhaled volatile anaesthetics are used commonly1 for maintenance of general anaesthesia. Given the low blood-gas partition coefficient of desflurane (0.42) and sevoflurane (0.69), a more rapid emergence from anaesthesia would be expected compared with the traditional inhalation anaesthetic isoflurane (1.43). We hypothesized that the use of the two less soluble volatile anaesthetics (desflurane and sevoflurane) for maintenance of general anaesthesia would provide a more rapid emergence than isoflurane after pulmonary surgery.

After thoracotomy, rapid emergence from anaesthesia in the immediate postoperative period is highly desirable1 to allow tracheal extubation with no residual ventilatory depression. Although isoflurane, desflurane and sevoflurane have been investigated extensively,2–4 no comparison of these inhalation anaesthetics has been made in pulmonary surgery where patients are generally unfit and surgery lasts at least 2 h.

In this study, we have compared maintenance and recovery characteristics after general anaesthesia with desflurane or sevoflurane with anaesthesia using isoflurane in patients undergoing pulmonary surgery.

Patients and methods

After obtaining approval from the Local Ethics Committee (Comité consultatif de protection des personnes dans la recherche biomédicale de Lille), 100 adults of both sexes, undergoing elective lobectomy or pneumonectomy were allocated randomly to one of three groups: sevoflurane, desflurane or isoflurane anaesthesia. Exclusion criteria were: age <18 yr, history of malignant hyperthermia, neuro-myo-pathic diseases and bleb emphysema on chest radiography necessitating exclusion of nitrous oxide.

Oral premedication comprised alprazolam 0.5 mg, 1 h before surgery. A forced air warming blanket (Warm Touch, Mallinckrodt) was used. Patient monitoring included routine continuous electrocardiography, non-invasive arterial pressure measurements and pulse oximetry (SPO2) (Datex AS/3 Anaesthesia System, Datex, Helsinki, Finland) were used. The non-invasive arterial pressure cuff was positioned on the dependent arm. After breathing 100% oxygen for 3 min, anaesthesia was induced with sufentanil 0.3 µg kg⁻¹, propofol 2 mg kg⁻¹ and atracurium 0.5 mg kg⁻¹. Ventilation was assisted manually as required, and tracheal intubation was performed with a double-lumen tube (Rusch, Kernen,
hypoxaemia: one-lung ventilation, the following were taken to indicate
5 min from induction until the end of operation. During
volatile anaesthetic concentrations were recorded every
6 extubation of 18
cars. Incidence of side effects (shivering) was recorded
their name, date of birth, and three names of flowers or
Mental recovery was assessed by asking patients to state
0–2 points for five physiological variables (motor activity,
respiration, circulation, consciousness and temperature).

Anaesthetic gas concentrations were monitored with a
multi-gas analyser (Datex AS/3 Anaesthesia System; Datex).
The expired concentration of volatile anaesthetic was
adjusted as necessary to maintain mean arterial pressure
(MAP) and heart rate (HR) within 20% of baseline values,
recorded before induction of anaesthesia (baseline). Additional
doses of sufentanil 0.15 µg kg⁻¹ were administered to
control acute haemodynamic changes that did not respond
within 5 min to a 50% increase in end-tidal concentration of
volatile anaesthetic. Ephedrine was administered if systolic
arterial pressure was less than 80 mm Hg, before placing
the patient in the lateral position. During maintenance,
tracheal 0.15 mg kg⁻¹ was administered as necessary for
neuromuscular block and was monitored using a peripheral
nerve stimulator. MAP, HR, \( P_{\text{E}} CO_2 \), nitrous oxide and
volatile anaesthetic concentrations were recorded every
5 min from induction until the end of operation. During
one-lung ventilation, the following were taken to indicate
hypoxaemia: \( S\text{PO}_2 < 95\% \), need for 100% inspired oxygen or
application of continuous positive airway pressure (CPAP).
After lobectomy or pneumonectomy was performed, no
further doses of sufentanil or atracurium were given. Nitrous
oxide was discontinued at the first skin suture. At the last
skin suture, the volatile agent was stopped and controlled
ventilation with 100% oxygen 10 litre min⁻¹ was continued
until end-tidal volatile anaesthetic concentration was less
than 0.1%.

From the time that the volatile anaesthetic was discontin-
tued until a positive response was obtained, patients were
asked, at intervals of 1 min, in a normal tone of voice, to
open their eyes and squeeze the investigator’s hand. The
trachea was extubated when a regular spontaneous breathing
pattern was re-established and when patients were able to
respond to verbal commands (open eyes, squeeze the
investigator’s hand). Open eyes and extubation times were
defined as emergence criteria. At 5 and 15 min after
extubation, recovery was assessed using the Aldrete score
and psychomotor function tests. The Aldrete score⁵ records
vital signs, with patients receiving 0–10 points, that is
0–2 points for five physiological variables (motor activity,
respiration, circulation, consciousness and temperature).
Mental recovery was assessed by asking patients to state
their name, date of birth, and three names of flowers or
cars. Incidence of side effects (shivering) was recorded
during the stay in the surgical intensive care unit.

Assuming from preliminary measurements a time for
extubation of 18±8 min with isoflurane, 30 patients would
be required in each group to detect a 40% difference in
this variable between groups (\( \alpha = 0.05 \) and \( (1–\beta) = 0.9\) ).⁶
All numerical values are expressed as mean (SD). Continuous
variables were analysed using analysis of variance (with
the Newman–Keuls test to assess differences between the
two groups). Descriptive variables were analysed using
Fisher’s exact test. \( P<0.05 \) was considered significant.
Between groups, comparison was made using the Mann–
Whitney exact test. Statistical analysis was calculated on
an IBM computer using SAS software (SAS Institute, Cary,
NC, USA).

Results
No patient was withdrawn from the study after randomiz-
ation. The three groups were comparable in number, age,
weight, sex distribution and ASA status. In addition, the
procedures performed and operating times were similar in
the three groups (Table 1). All patients underwent identical
procedures by the same group of surgeons and anaesthetists.

During maintenance of anaesthesia, mean values,
expressed as MAC of end-tidal concentration, recorded
eye every 5 min were higher \( (P=0.04) \) for sevoflurane \( (1.4 \text{ (SD}
0.6\%)(0.9\text{ MAC})) \) than for either desflurane \( (3.4 \text{ (0.9\%}(0.6\text{ MAC})) \)
sevoflurane \( (0.7 \text{ (0.3\%}(0.6\text{ MAC})) \) (Fig. 1).
MAC values were calculated by taking the published MAC

Table 1 Characteristics of patients (mean (SD or range). No significant
differences between groups

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Isoflurane</th>
<th>Desflurane</th>
<th>Sevoflurane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lobectomy</td>
<td>27</td>
<td>29</td>
<td>22</td>
</tr>
<tr>
<td>Pneumonectomy</td>
<td>7</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>Duration (min)</td>
<td>180 (57)</td>
<td>182 (65)</td>
<td>163 (72)</td>
</tr>
</tbody>
</table>
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Fig 2 Heart rate (HR) and mean arterial pressure (MAP) before induction of anaesthesia (baseline (B)), after induction (Ind.), before skin incision (Inc.) and at the indicated times during maintenance of anaesthesia with sevoflurane, desflurane or isoflurane (mean (SD)). *P<0.05, isoflurane vs sevoflurane; †P<0.05, isoflurane vs sevoflurane and desflurane.

Table 2 Hypoxaemic events during one-lung ventilation. CPAP—Continuous positive airway pressure. No significant differences between groups

<table>
<thead>
<tr>
<th></th>
<th>Isoflurane (n=34)</th>
<th>Desflurane (n=37)</th>
<th>Sevoflurane (n=29)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( S_{O_2} &lt; 95% )</td>
<td>16</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>( F_{I_2} O_2 = 100% )</td>
<td>9</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>CPAP</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

value for a 60-yr-old population with a 100% oxygen mixture.7–9

Intraoperative use of atracurium was similar in the three groups: 83 (25) mg with sevoflurane, 91 (29) mg with desflurane and 85 (23) mg with isoflurane (P=0.71). Mean sufentanil consumption was 68 (20) mg with sevoflurane, 74 (16) mg with desflurane and 68 (18) mg in the isoflurane group (P=0.34).

Intraoperative changes in MAP and HR are summarized in Figure 2. MAP and HR remained within 20% of baseline values. There were no differences between groups in the use of ephedrine (two, one and three patients for sevoflurane, desflurane and isoflurane, respectively). Intraoperative HR appeared similar between groups except at 60 min between isoflurane and desflurane or sevoflurane. MAP was significantly lower in the isoflurane group compared with the sevoflurane group at 90, 120, 150 and 180 min.

There were no differences between groups in incidence of peroperative hypoxaemia during one-lung ventilation (Table 2).

Times from cessation of administration of the anaesthetic agent to eye opening, extubation and correct stating of name, date of birth and three names of flowers or cars were significantly shorter in the desflurane group (Figs 3, 4). Emergence time for eye opening was 7.2 (4.8) min for desflurane, 13.7 (8.6) min for sevoflurane and 14.3 (11.0) min for isoflurane (P<0.0001). The trachea was extubated after 8.9 (5.0) min with desflurane, 18.0 (17.0) min with sevoflurane and 16.2 (11.0) min with isoflurane (P<0.0001).

Five and 15 min after tracheal extubation, recovery, as assessed by the Aldrete score, was better for desflurane compared with isoflurane and sevoflurane (Fig. 4A). Although early return of cognitive function (state name, date of birth, three flowers or cars) at 5 min was more efficient after desflurane, there was no significant difference after 15 min (Fig. 4B).

The incidence of shivering was five of 34, four of 37 and 11 of 29 patients in the sevoflurane, desflurane and isoflurane groups, respectively (P<0.01 between isoflurane and sevoflurane or desflurane group).

Discussion

We have performed a prospective comparison of maintenance and recovery after general anaesthesia with sevoflurane, desflurane and isoflurane in patients undergoing pulmonary surgery. We obtained similar arterial pressure, heart rate and arterial oxygenation values throughout anaesthesia. However, emergence and early recovery were twice as fast with desflurane than with sevoflurane or isoflurane.

In pulmonary surgery, general anaesthesia can be associated with supplementary anaesthetic techniques (epidural anaesthesia, interpleural anaesthesia). These techniques were deliberately not used in this study to limit variability. Hypnosis can be maintained with i.v. anaesthesia (propofol) or inhaled volatile anaesthetics. Volatile agents are used commonly for their dose-related direct bronchodilatory effect in patients with reactive airways.

During maintenance of anaesthesia, a higher (P=0.04) end-tidal concentration based on MAC was required for sevoflurane (0.9 MAC) than for either desflurane (0.6 MAC)
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Fig 4 Proportion of patients who achieved an Aldrete recovery score of 10 (\(A\)) and were able to give their name, date of birth or three names of flowers or cars, 5 and 15 min after discontinuation of anaesthesia (\(B\)). *\(P<0.05\); **\(P<0.01\), desflurane vs isoflurane and sevoflurane.

or isoflurane (0.6 MAC). Similar intraoperative medications (sufentanil, atracurium) were used in the three groups. Sufentanil was chosen for its minimal haemodynamic depressant effects during surgery and its benefits on early emergence from anaesthesia compared with morphine or fentanyl, because it is less cumulative.11

Stable cardiovascular conditions were achieved easily with the three anaesthetics. In previous studies, sevoflurane and desflurane did not differ in cardiovascular effects.12 However, sevoflurane was associated with a slower heart rate than isoflurane,13 and desflurane with a more rapid heart rate than isoflurane at more than 1 MAC.14 We did not find these effects in this study. MAP was maintained within 20% of baseline values during maintenance with all three anaesthetics.15

An undesirable effect of inhalation anaesthetics is inhibition of hypoxic pulmonary vasoconstriction (HPV).1 In the few studies carried out in humans, halothane or isoflurane caused none or only a slight decrease in HPV response.16 17 We found that a decrease in \(S_pO_2\) occurred frequently during one-lung ventilation in the lateral decubitus position,1 but there was no difference between the three anaesthetics with regard to arterial oxygenation (\(S_pO_2<95\%), need for 100% inspired oxygen or application of CPAP) during one-lung ventilation. A more precise assessment of the effects of the volatile anaesthetics on oxygenation and haemodynamics during one-lung ventilation would have required more extensive measurements that were beyond the scope of our study.

Previous studies have compared speed of emergence time from sevoflurane or desflurane anaesthesia vs isoflurane in ambulatory procedures,2–4 surgery of moderate20 and long duration21 22 or in elderly patients.21 Patients recovered approximately twice as fast from sevoflurane or desflurane anaesthesia as from isoflurane at each MAC concentration. No previous study compared emergence times of sevoflurane, desflurane and isoflurane after prolonged exposure. We found that with patients who were older, less fit, and where surgical procedures lasted at least 2 h, average emergence times from desflurane anaesthesia were correspondingly greater than those from sevoflurane and isoflurane anaesthesia. The SD of emergence times were correspondingly greater after sevoflurane and isoflurane, some patients having significantly prolonged emergence times after sevoflurane and isoflurane anaesthesia. In this study, the lower blood/gas solubility of sevoflurane did not predict rapid emergence after pulmonary surgery as with desflurane. In addition, emergence after desflurane was more predictable for each patient.

Different tests can be used to evaluate recovery. The
Aldrete score was used in this study to assess progress of vital signs during recovery and as part of the evaluation of readiness. However, this scoring system does not fully assess cognitive function. Psychometric tests have been used to complete progress of recovery. Differences in early recovery between sevoflurane or desflurane anaesthesia compared with isoflurane, but not in later recovery, have been demonstrated previously. In pulmonary surgery, faster early recovery at 5 min (Aldrete score, psychomotor tests) was demonstrated only for desflurane compared with sevoflurane and isoflurane anaesthesia. No difference in early recovery after sevoflurane or isoflurane anaesthesia was noted.

In conclusion, pulmonary surgery patients anaesthetized with desflurane showed faster emergence and recovery times than isoflurane, as expected. Desflurane and sevoflurane differed despite similar blood-gas partition coefficients. A possible explanation could be the higher dose of sevoflurane (0.9 vs 0.6 MAC for desflurane and isoflurane) required during anaesthesia to maintain mean arterial pressure and heart rate within 20% of baseline values. Slower awakening after long anaesthesia with sevoflurane may also be consistent with the greater solubility of sevoflurane in blood, lean tissues and fat than desflurane, in addition to the effects of degradation products of sevoflurane.

In conclusion, sevoflurane and isoflurane with desflurane provided similar haemodynamic effects and arterial oxygenation. Rapid emergence and early recovery were significant benefits associated with desflurane but the clinical benefits remain to be demonstrated.

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