Minimal and medium flow anaesthesia with isoflurane and desflurane: Effects on inspired and expired oxygen and anaesthetic gas concentrations
T Togal, S Demirbilek, A Koroglu, O Ersoy

Citation

Abstract
Background: In this study we aimed to compare haemodynamics, body temperature, inspired and expired oxygen and anaesthetic gas concentrations in minimal and medium flow anaesthesia with isoflurane and desflurane.
Methods: We studied 60 ASA 1-2 patients undergoing elective surgical procedures. Patients were randomly divided to two equal main groups to receive isoflurane and desflurane. Then these main groups were randomly divided to 3 equal sub-groups such as to receive isoflurane or desflurane in 500, 1000 and 2000 ml.min⁻¹ fresh gas flow (FGF) respectively. FGF was applied 4 L min⁻¹ in initial phase (10 min) after standard anaesthetic induction, then isoflurane and desflurane concentrations were adjusted as 1.5 % and 6 % respectively and FGF was adjusted according to groups. HR, MAP, SpO₂ oesophageal temperature, vaporizer settings, inspired and expired anaesthetic gas concentrations were recorded at regular intervals throughout the study.
Results: Inspired and expired anaesthetic concentrations were decreased significantly in minimal flow groups compared to medium and high flow groups. FiO₂ values were decreased parallel to duration of anaesthesia. Low FiO₂ occurred in 2 cases in minimal flow isoflurane group and 8 cases in minimal flow desflurane group.
Conclusion: Isoflurane and desflurane could be used safely with minimal and medium FGF, but we decided that isoflurane was superior to desflurane regarding oxygenation. We thought that there was hypoxia risk in cases which desflurane was used as inhalant agent in minimal flow with 50 % N₂O in O₂. However, we concluded that the increasing FiO₂ % ratio can prevent hypoxia.

INTRODUCTION
There is increasing interest in the subject of inhalation anaesthesia using low rates of fresh gas flow. The reasons for this interest are not hard to discover. The lower the fresh gas flow, the less do anaesthetic agents pollute the environment. Very considerable reductions in the cost of expensive agents can be made (1). The major risks which have been identified if low-flow anaesthesia is used inappropriately are accidental hypoxia, over- or under dosage of volatile anaesthetics, hypercapnia, and accumulation of potentially toxic trace gases (2).

In low-flow anaesthesia, there is a marked difference between the fresh gas concentration of the anaesthetic and its concentration within the breathing system, and this difference increases with the decreasing fresh gas flow, but decreases with decreasing solubility of the anaesthetic agent such as desflurane. If the concentration of the volatile anaesthetic shall be changed, the vaporizer has to be adjusted to a concentration considerably exceeding the aspired nominal value (3).

Isoflurane is considered to be the most suitable of the group of older anaesthetic agents to be used in low flow systems (4). It was reported that desflurane is suitable for low flow techniques with maximum output vaporizer. In addition, due to low blood/gas solubility of desflurane, it may be superior to isoflurane when used in low flow anaesthesia (5).

In this study, we aimed to compare haemodynamics, body temperature, inspired and expired oxygen and anaesthetic gas concentrations in minimal and medium flow anaesthesia with isoflurane and desflurane.

METHODS
With institutional ethics committee approval and written,
informed consent from the subjects, we studied sixty ASA
1-2 patients undergoing elective surgical procedures.
Patients with acute or chronic pulmonary, cardiac or
metabolic disease, hepatic or renal dysfunction, anaemia,
weight over ideal body weight of 30% or under 50 kg,
history of current or past smoking or alcohol addiction, and
younger than 18 years old were excluded from the study.

Patients were randomly divided to two equal main groups to
receive isoflurane (group I, n: 30) and desflurane (group D,
n: 30). Then these main groups were randomly divided to
three equal sub-groups such as to receive isoflurane or
desflurane in 500 ml.min⁻¹ fresh gas flow (group I₁,
group D₁, n: 10), 1000 ml.min⁻¹ fresh gas flow (group I₂,
group D₂, n: 10), 2000 ml.min⁻¹ fresh gas flow (group I₃,
group D₃, n: 10) respectively. We used Cato workstation
(Drager Cato Edition Luebeck, Germany) with isoflurane
and desflurane vaporizer. Oxygen, nitrous oxide, isoflurane
and desflurane concentrations were measured with (200
mL.min⁻¹ sampling speed) side stream gas analyser by
galvanic cell principal and under red light absorption
spectrophotometer. Anaesthetic machine and all analysers
were calibrated before use, according to the instructions of
the manufacturers. Fresh soda-lime, disposable circle system
and bacterial filter were used in each patient. Operating
room temperature was set at 21 °C.

Eight, and 2 hours before inducing anaesthesia, all patients
were premedicated with diazepam 5 mg orally. Heart rate,
oxygen saturation (SpO₂ %), non invasive arterial blood
pressure were monitored in operating room. Heart rate (HR,
beat.min⁻¹), mean arterial pressure (MAP, mmHg), and
SpO₂ were recorded preoperatively. Patients received
lactated ringer solution 5 ml. kg⁻¹.h⁻¹ intravenously (i.v.)
during surgery.

Anaesthesia was induced in both groups with lidocaine 1.0
mg.kg⁻¹, fentanyl 1 µg.kg⁻¹ and thiopental 5 mg.kg⁻¹ i.v.
after one min pre-oxygenation with oxygen 100 % in fresh
gas flow of 10 L.min⁻¹. A single dose of vecuronium 0.1
mg.kg⁻¹ was given to facilitate orotracheal intubation. After
tracheal intubation, controlled ventilation was adjusted to
maintain the end-tidal carbon dioxide at (EtCO₂) 30-35
mmHg, and SpO₂ 97-100 % (fixed respiratory rate of 12 per
min, tidal volume variable).

All cases were monitored by oesophageal temperature probe,
spirometer, and gas analyser.

During the initial phase, lasting 10 min, the fresh gas flow
was set to 4 L.min⁻¹ (O₂ 2 L.min⁻¹, N₂O 2 L.min⁻¹). Then
isoflurane and desflurane concentration were set 1.5 % and 6
% respectively and after initial phase the fresh gas flow was
reduced to 500, 1000 or 2000 L.min⁻¹ according to group
design. Oxygen and nitrous oxide fresh gas concentrations
were set to 50 % nitrous oxide in oxygen.

If the inspired oxygen concentration (FiO₂) decreased to less
than 30 % during maintenance of anaesthesia, oxygen flow
was increased 0.5 L.min⁻¹ and simultaneously nitrous oxide
flow decreased 0.5 L.min⁻¹. Fresh gas flow decreased again,
once FiO₂ increased to 40 % by this setting.

Control of depth of anaesthesia depended primarily on MAP
in relation to a reference preoperative value. Therefore, first,
MAP was measured three times, at intervals, during the
preoperative visit and twice in the anaesthesia room. The
mean of the two lowest of these three measurements was
taken as the baseline MAP. Thereafter, signs of light
anaesthesia (increase in MAP or HR >20 % above baseline,
patient movement, and sweating) were treated with,
increasing concentrations of isoflurane or desflurane.

Additional bolus doses of fentanyl1 (0.5 µg.kg⁻¹ i.v.) were
also allowed to control acute haemodynamic changes that
did not respond to an increase in the inspired concentration
of isoflurane or desflurane. If hypotension was occurred (the
MAP decreased by more than 20 %), a single dose of
ephedrine (5 mg i.v.) was allowed.

HR, MAP, SpO₂ were recorded after induction of
anaesthesia. In addition, oesophagus temperature (°C),
vaporizer gas concentration, inspired anaesthetic gas
concentration (FiAN), end-tidal anaesthetic gas
concentration (FetAN), FiO₂ %, expired oxygen
concentration (FetO₂ %), inspired nitrous oxide
concentration (FiN₂O %), expired nitrous oxide
concentration (FetN₂O %) at 1, 5, 10, 15 min, and
then in 15 min intervals to 150 min were recorded after
intubation.

At the end of surgery, in both groups administration of
inhaled gases was terminated and the lungs were ventilated
with oxygen 100 % in a fresh gas flow of 4 L.min⁻¹. After
obtaining spontaneous breathing, residual neuromuscular
block was reversed with atropine 0.02 mg.kg⁻¹ and
neostigmine 0.05 mg. kg⁻¹. When breathing was adequate,
the trachea was extubated. After extubation HR, SAP, DAP,
and MAP were recorded. The patient was observed in the
recovery room for one hour. The patient was then returned to the ward.

Statistical analyses of the study were performed using SPSS for Windows, version 10.0 (SPSS Inc., Chicago, IL, USA). Numerical variables in the two groups were compared by the paired t-test when data were normally distributed; otherwise the Wilcoxon signed rank test was used. The Mann–Whitney U test was used to compare demographic data, as appropriate. P values < 0.05 were considered statistically significant. The data were presented as mean ± SD, median (range) or as a percentage as appropriate.

RESULTS

The groups were similar with respect to sex, age, height, weight, body surface area, duration of anaesthesia, and duration of surgery (table 1).

Figure 1

Table 1: Patient characteristics and data concerning the duration of anaesthesia and surgery of the groups. (Values are means ± SD)

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>Group I (n=30)</th>
<th>Group II (n=30)</th>
<th>Group III (n=30)</th>
<th>Group IV (n=30)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recovery</td>
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<td>8.6±15.3</td>
<td>10.2±7.9</td>
<td>9.0±6.7</td>
</tr>
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<td>11.2±11.5</td>
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<td>10.2±11.8</td>
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<td>6.5±16.1</td>
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<td>10</td>
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<td>6.5±14.2</td>
<td>8.6±11.1</td>
<td>9.1±12.0</td>
</tr>
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<td>15</td>
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<td>7.6±15.1</td>
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</tr>
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<td>20</td>
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<td>7.5±14.3</td>
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<td>7.4±11.0</td>
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</tr>
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<td>75</td>
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<td>7.6±12.0</td>
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</tr>
<tr>
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<td>7.8±10.0</td>
</tr>
<tr>
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<tr>
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<td>7.7±8.9</td>
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</tr>
</tbody>
</table>

There was no significant difference between the HR and MAP values of groups preoperatively and during anaesthesia.

No arrhythmia was occurred during anaesthesia. Any patients required ephedrine to treat hypotension.

Vaporizer concentrations were significantly higher in group D than group I during anaesthesia (p<0.05) (table 3).
Minimal and medium flow anaesthesia with isoflurane and desflurane: Effects on inspired and expired oxygen and anaesthetic gas concentrations

Figure 3
Table 3: Vaporizer concentration settings (%)

<table>
<thead>
<tr>
<th>Time(min)</th>
<th>Group I</th>
<th>Group I2</th>
<th>Group I3</th>
<th>Group D1</th>
<th>Group D2</th>
<th>Group D3</th>
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<td>1.500</td>
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<td>0.600</td>
<td>0.600</td>
</tr>
<tr>
<td>5</td>
<td>1.500</td>
<td>1.500</td>
<td>1.500</td>
<td>0.600</td>
<td>0.600</td>
<td>0.600</td>
</tr>
<tr>
<td>10</td>
<td>1.500</td>
<td>1.500</td>
<td>1.500</td>
<td>0.600</td>
<td>0.600</td>
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</tr>
<tr>
<td>15</td>
<td>1.500</td>
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<td>1.500</td>
<td>0.600</td>
<td>0.600</td>
<td>0.600</td>
</tr>
<tr>
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<td>1.400</td>
<td>0.500</td>
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<td>1.400</td>
<td>0.500</td>
<td>0.500</td>
<td>0.500</td>
</tr>
<tr>
<td>60</td>
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<td>1.400</td>
<td>0.500</td>
<td>0.500</td>
<td>0.500</td>
</tr>
<tr>
<td>75</td>
<td>1.400</td>
<td>1.400</td>
<td>1.400</td>
<td>0.500</td>
<td>0.500</td>
<td>0.500</td>
</tr>
<tr>
<td>90</td>
<td>1.400</td>
<td>1.400</td>
<td>1.400</td>
<td>0.500</td>
<td>0.500</td>
<td>0.500</td>
</tr>
</tbody>
</table>

*Vaporizer concentrations were significantly higher in desflurane groups than isoflurane groups during anaesthesia (p<0.05).

FiAN was significantly higher in group I1 than group I2 at 10th min after intubation, and than group I3 between 15th and 90th min. FiAN was significantly lower in group D1 than group D2 and D3 between 15th - 30th min. FetAN was significantly lower in group I1 than group I2 and I3 between 30th - 105th min. In group D1 FetAN was significantly lower than group D2 and D3 at 30th min (table 4).

Figure 4
Table 4: Inspired and expired anaesthetic agent concentrations of groups (%). (n:10).

FiCO2 was never increased above zero in groups. Only in one case from group I1, SpO2 and EtCO2 were decreased to 97% and 30 mmHg respectively at 90th min after intubation. At the same time FiO2 was higher than 30%, therefore, fresh gas flow was increased to 6 L.min⁻¹ for 5 min. Two cases in group I1 and 8 cases in group D1, FiO2 was decreased less than 30% (table 5).

Figure 5
Table 5: Patients who fresh gas flow changed, time of decreasing FiO2 %↓ (min) and changed gas flows.

*Cases who fresh gas flow changed two times.

FiO2 decreased less than 30% in 2 patients in minimal flow isoflurane group (group I1) and 8 patients in minimal flow desflurane group (group D1).

The lowest FiO2 was 42% in group I2 and I3, 38% in group D2 and 41% in group D3. In table 6 demographic characteristics, duration of surgery and anaesthesia were detailed of the cases which fresh gas flow was changed.

*Inspired and expired anaesthetic concentrations decreased significantly in minimal flow groups (group I1 and group D1) during anaesthesia.
Minimal and medium flow anaesthesia with isoflurane and desflurane: Effects on inspired and expired oxygen and anaesthetic gas concentrations

Figure 6
Table 6: Demographic characteristics, duration of surgery and anaesthesia of the cases which fresh gas flow was changed. (Values are means ± SD).

<table>
<thead>
<tr>
<th>FGFlow changed</th>
<th>FGFlow changed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (♂/♀)</td>
<td>5/15</td>
</tr>
<tr>
<td>Age (years)</td>
<td>36.52±6.84</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>64.26±7.70</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>168.4±7.92</td>
</tr>
<tr>
<td>BSA (kg/m²)</td>
<td>1.7±0.01</td>
</tr>
<tr>
<td>Duration of anaesthesia</td>
<td>153.5±44.10</td>
</tr>
<tr>
<td>Duration of surgery</td>
<td>139.0±63.29</td>
</tr>
</tbody>
</table>

FGF: Fresh gas flow

FiO₂ was significantly lower in group I1 than group I2 and I3, in group D1 than group D2 and D3 at 30th min. FiO₂ was significantly lower in group D1 than group I1 at 10th min. FiO₂ was significantly lower in group I1 than group D2 and D3, in group D1, D2, D3 than group I2, in group D2 and D3 than group I3 at 10th min after intubation (figure 1, figure 2).

Figure 7
Figure 1: Inspired oxygen concentrations in isoflurane group.

FiO₂ concentration decreased significantly in minimal flow isoflurane group (group I1) than medium and high flow groups.

Figure 8
Figure 2: Inspired oxygen concentrations in desflurane group.

FiO₂ concentration decreased significantly in minimal flow desflurane group (group D1) than medium and high flow groups.

FetO₂ was significantly lower in group I1 than group I2 and I3, in group D1 than group D2 and D3 at 30 min. FetO₂ was significantly lower in group I1 than group D1 at 5th, 10th, 15th, 25th, 60th, 75th, 90th and 105th min after intubation. FetO₂ was significantly lower in group I1 than group D2 and D3 at 10th min. FetO₂ was significantly lower in group I1 than group D1 at 5th, 10th, 15th, 25th, 60th, 75th, 90th and 105th min after intubation. FiN₂O concentration was significantly higher in group D1 than group D2 and D3 between 45th and 105th min and than group I3 between 60th and 105th min. In group I2, FiN₂O was lower at 5th min and higher at 90th min than group D1. In group D1, FetN₂O was significantly higher between 60th and 105th min than group D2. In group D1 FetN₂O was significantly higher between 45th and 120th min than group D3. In group I3, FetN₂O was significantly higher between 60th and 105th min than group D1 (table 7).
Minimal and medium flow anaesthesia with isoflurane and desflurane: Effects on inspired and expired oxygen and anaesthetic gas concentrations

Figure 9
Table 7: Expired oxygen concentration during anaesthesia (%). (n:10)

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
<th>Group IV</th>
<th>Group V</th>
<th>Group VI</th>
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<td>1</td>
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<td>64.3±5.2</td>
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<td>5</td>
<td>50.7±1.8</td>
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<td>49.2±1.8</td>
</tr>
<tr>
<td>10</td>
<td>46.8±1.0</td>
<td>46.5±2.1</td>
<td>47.1±2.8</td>
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<tr>
<td>30</td>
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<td>43.3±1.3</td>
<td>43.7±1.5</td>
<td>37.8±2.6*</td>
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<tr>
<td>60</td>
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<td>41.7±1.8</td>
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<tr>
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<td>37.7±0.7</td>
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<tr>
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<td>29.8±2.2</td>
<td>37.2±1.3</td>
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</tbody>
</table>

* Expired oxygen concentration decreased significantly in minimal flow groups (group I and group D1) after 30 min of intubation than other groups (p<0.05).

There were no significant differences between groups regarding body temperature during anaesthesia (table 8).

Figure 10
Table 8: Inspired and expired nitrous oxide concentration (%). (n:10)

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
<th>Group IV</th>
<th>Group V</th>
<th>Group VI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>67.3±3.6</td>
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<td>42.5±1.3</td>
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<tr>
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Inspired and expired nitrous oxide concentrations increased parallel to duration of anaesthesia in all groups.

DISCUSSION

When low flow anaesthesia was used with inhalant agents, it was known that uptake of the anaesthetics was almost constant after equilibrium with initial phase and during inhalation anaesthesia, it was reported that uptake of volatile anaesthetics changed insignificantly (1). In low flow inhalation anaesthesia; high re-breathing ratio has great effect on exhaled gas configuration and concentration within breathing system (2). Due to its specific pharmacokinetic properties, only the fresh gas desflurane concentration can be maintained unchanged. Desflurane concentration can be reached to 85% in fresh gas flow after ten minutes of administration. However, due to its low anaesthetic potency, MAC value changes between 4-8% depending on age, so it was required high alveolar concentration (2).

According to guidelines of low flow anaesthesia, during the initial phase lasting 10 to 15 minutes, a high fresh gas flow has to be used. This phase guarantees inspired oxygen of at least 30% in most of patients. If the flow would be reduced too early to low values, inevitably gas volume deficiency would result compromising adequate ventilation (2). The following settings of the vaporizers are used routinely during the initial phase: isoflurane 1-1.5 %, and desflurane 4.0 to 6.0%. If these settings are used over the first 10 to 15 minutes, an expired concentration of about 0.7 to 0.8 times the MAC of the respective volatile agent will be gained (2).

In our study, during initial phase, isoflurane and desflurane concentrations were arranged as 1.5%, 6% respectively. After initial phase, isoflurane and desflurane concentration were increased to 2%, 8% respectively. Sufficient end tidal anaesthetic values were gained with these vaporizer settings. The difference of vaporizer settings between groups was a result of different MAC values of these agents (2). In our study, inspired and expired concentration of anaesthetics was decreased in a short time in desflurane group compared to isoflurane group when minimal flow used. This can be explained with lower blood /gas partition coefficient of desflurane, because it is saturated and eliminated from tissues quickly (2).

Smith (10) reported that there was no relation between concentration of oxygen, nitrous oxide and anaesthetic gas in fresh gas flow, when fresh gas flow was lower than 0.9 L.min⁻¹. However, if a gas mixture was inhaled during low flow anaesthesia, there might be a significant difference between FiO₂ and oxygen concentration in fresh gas flow.
Flow reduction will lead to a significant increase of re-breathing. The inspired gas, thus, contains a markedly increased proportion of the exhaled gas which already had passed the patient's lung and contains less oxygen. The resulting decrease of oxygen content in the gas mixture has to be compensated by increasing the fresh gas oxygen content, which must be the higher; the lower is the flow. During the course of anaesthesia, the consumption of oxygen is constant in haemodynamic stability and oxygen is taken up constantly by the patient in the range of the basal metabolic needs. In addition N2O absorption is determined by alveolar-arterial pressure difference, because it is not metabolized. Absorption is high at the beginning but it decreases as tissue N2O concentration level increases. In normal weighing adults N2O concentration is 60-65% provides maximum analgesia and amnesia. At that time this ratio is concordant with recommended 30% oxygen concentration.

In our study, after the initial period by decreasing the fresh gas flow rate FiN2O level increased as FiO2 level decreased concordant with the known effects of low flow anaesthesia on inspired gas concentrations. However FiO2 level decreased less than 30% especially in minimal flow groups. So O2 and N2O flows were set reversely as 30 mL.min\(^{-1}\) units and FiO2/FiN2O ratio preserved 50-50 %. Only in one case oxygen saturation decreased below 97% and system was needed to be washed with high flow. In principle, the accumulation of nitrogen in the breathing system can lead to a reduction in the concentration of oxygen as well as nitrous oxide. A reduction of nitrous oxide gas concentration is not a problem, though it may lead to a weakening of the effect of nitrous oxide. In our groups FiO2-FiN2O sum was at least 85 % and this showed that there was no significant nitrogen accumulation.

Okada et al. used isoflurane with 600 mL.min\(^{-1}\) fresh gas flow in their study and reported that oxygen consumption could be more than oxygen requirement and hypoxia could be occurred because of N2O saturation. They suggested that with 600 mL.min\(^{-1}\) fresh gas flow in high weighted cases, consumption could not be supported. In our study, low FiO2 occurred in more cases in minimal flow anaesthesia with desflurane. This can be explained by desflurane reaction with soda-lime. It is known that reaction of inhaled agents and carbon dioxide absorbents increased in low flow anaesthesia. Carbon monoxide which has high solubility and tissue affinity is mostly formed with desflurane soda-lime reaction. But in low flow systems when the absorbent humidity is conserved, carbon monoxide production is very low without clinical importance. For decrease this risk and to avoid hypercapnia it is recommended that soda-lime canisters should be changed frequently. In this study carbon dioxide absorbent was refreshed for every case.

If we criticise our study according to disadvantages of low flow anaesthesia practices, we can say that this technique is safe clinically due to no decrease of SpO2 below 97%, except one case, no arrhythmia development and no increase of FiCO2 above zero. However our cases were from ASA I physical status and duration of anaesthesia was not exceeded above 200 min. So this technique should be studied in cases with proceeding diseases and with long duration of anaesthesias.

Although heat humidity exchanger was not used in our cases, heat conservation effect was seen after 30 th min of low flow anaesthesia. This effect can be explained with heat conservation effect of inspired gases.

As a result we concluded that isoflurane and desflurane in minimal and low flow anaesthesia were not affecting on haemodynamics. They could be used safely with 500-1000 mL.min\(^{-1}\) fresh gas flows, but we decided that isoflurane was superior to desflurane regarding oxygenation in minimal flow. We thought that there was hypoxia risk in cases which desflurane was used as inhalant agent in 500 mL.min\(^{-1}\) fresh gas flow with 50% N2O in O2. However, we concluded that the increasing FiO2 % ratio can prevent hypoxia. We thought that there was no difference between 1000-2000 mL.min\(^{-1}\) fresh gas flows with 50% N2O in oxygen regarding oxygenation.

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References

2. Baum JA, Aitkenhead AR. Low-flow anaesthesia.
Minimal and medium flow anaesthesia with isoflurane and desflurane: Effects on inspired and expired oxygen and anaesthetic gas concentrations

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