INHALATION INDUCTION OF ANAESTHESIA WITH ISOFLURANE: EFFECT OF ADDED CARBON DIOXIDE

S. A. COLEMAN, J. W. McCORRY, C. J. VALLIS AND R. J. BOYS

SUMMARY
Fifty children underwent inhalation induction of anaesthesia with isoflurane and nitrous oxide in oxygen with or without the addition of 5% carbon dioxide. Addition of carbon dioxide resulted in more rapid induction and significantly reduced the incidence and severity of airway related problems.

KEY WORDS

Inhalation induction of anaesthesia is a popular technique in paediatric practice. Halothane is a safe agent with a low incidence of side effects, even after repeated use. Isoflurane has the advantages of lower blood solubility and fewer adverse cardiovascular effects [1]. Its metabolism is minimal and this may reduce the potential for organ toxicity following repeated exposure. However, the irritant effect of isoflurane on the airway may cause respiratory complications which prolong induction and produce significant reductions in oxygen saturation in up to 50% of children [2, 3]. Premedication may reduce, but does not eliminate, these complications [4–6].

Addition of carbon dioxide to inspired gases stimulates ventilation and may reduce the incidence of breath-holding and laryngospasm. Unlike halothane, isoflurane has not been shown to potentiate cardiac arrhythmias in the presence of hypercapnia [1, 7–9]. This study was designed to assess the effect of addition of 5% carbon dioxide to inspired gases during inhalation induction of anaesthesia with isoflurane.

PATIENTS AND METHODS
Approval of the District Ethics Committee and informed parental consent were obtained for the study.

Following i.m. premedication with atropine 0.015 mg kg⁻¹, 50 children (ASA I, weight 4–15 kg) were allocated randomly to one of two groups: group A (n = 25) received inhalation induction of anaesthesia with isoflurane and nitrous oxide in 30% oxygen; group B (n = 25) received the same anaesthetic mixture, but with the addition of 5% inspired carbon dioxide. Fresh gas flows of 10 litre min⁻¹ were administered via facemask and Ayre's T-piece, with Jackson-Rees modification. The inspired isoflurane concentration was increased by 0.5% increments, as tolerated clinically, to a maximum of 5%.

The anaesthetics were administered by one of two anaesthetists with limited previous experience of inhalation induction with isoflurane. Patients were monitored using continuous electrocardiography, digital pulse oximetry (Biox 3700) and capnography (Engstrom Erica). Capnograph sampling tubing was connected to a modified angle-piece which allowed sampling of expired gases to occur at the patients lips. An observer recorded heart rate, oxygen saturation (SpO₂) and percentage expired carbon dioxide at 30-s intervals, with additional recordings if SpO₂ decreased to less than 85%. Times to onset of regular ventilation, insertion of oropharyngeal airway and attainment of 5% inspired isoflurane were noted. Coughing, breath-holding, laryngospasm, salivation or struggling were recorded, together with the smallest associated value of SpO₂. The anaesthetist was informed if SpO₂ decreased to less than 85% and he was allowed to abandon the induction technique at any time if clinically indicated.

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Differences in continuous measurements between groups were assessed using Student's two-sample $t$ test, with Welch's correction when variances were significantly different. When distributions were particularly skewed, a logarithmic transformation was performed before testing and hence geometric, rather than arithmetic, means are quoted. The $2 \times 2$ tables were analysed using Fisher's exact test.

The significance of factors affecting induction times was obtained by multiple linear regression and that of factors affecting complication rates, using a logistic model. In a logistic model, the log odds of a complication are related to a linear combination of the factors.

RESULTS

The groups were similar in age, weight and sex distribution (table I).

Time to attainment of 5% inspired isoflurane was significantly shorter in patients breathing additional carbon dioxide (group B) (fig. 1) (mean time 3.1 min compared with 4.8 min; $P < 0.01$).

The number of patients with complications was significantly fewer in group B (8% compared with 44% in group A; $P < 0.05$) (table II). The number of instances of coughing, breath-holding and laryngospasm was reduced significantly in group B (table III). Salivation and struggling were also less frequent in group B, but these incidences were not significantly different. Cardiac arrhythmia was not detected in any child and mean maximum heart rates were similar in both groups.

Mean maximum expired carbon dioxide in group A was 5.4% (range 3.9–9.0%), compared with 7.6% (range 5.5–9.0%) in group B (fig. 2).

The incidence of complications was not related to age, weight or sex of the child. The incidence did not differ between the two anaesthetists, and no decrease in incidence or severity of complications was observed as the study progressed.

All 25 children in group B maintained $Sp_{O_2} > 85\%$, compared with 21 children in group A (fig. 3). Cyanosis was detected in three children, all in group A.

DISCUSSION

In previous studies of unpremedicated children, induction of anaesthesia with isoflurane was

![Graph](image-url)
### TABLE III. Number of complications during induction of anaesthesia with isoflurane with or without added carbon dioxide

<table>
<thead>
<tr>
<th></th>
<th>Without CO₂ (n = 25)</th>
<th>With CO₂ (n = 25)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cough</td>
<td>6</td>
<td>0</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>Breath-holding</td>
<td>8</td>
<td>0</td>
<td>&lt; 0.005</td>
</tr>
<tr>
<td>Laryngospasm</td>
<td>11</td>
<td>2</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Salivation</td>
<td>5</td>
<td>0</td>
<td>0.05</td>
</tr>
<tr>
<td>Struggling</td>
<td>5</td>
<td>1</td>
<td>ns</td>
</tr>
<tr>
<td>Arrhythmia</td>
<td>0</td>
<td>0</td>
<td>ns</td>
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</tbody>
</table>

Fig. 2. Maximum expired carbon dioxide percentages during induction of anaesthesia.

Fig. 3. Minimum oxygen saturations during induction of anaesthesia.

Associated with an incidence of airway related complications of between 21 and 67% [10, 11]. Comparison of $SpO_2$ in unpremedicated children during inhalation induction with isoflurane or halothane revealed significant desaturation in up to 50% of those receiving isoflurane [2, 3]. Sedative premedication may reduce the incidence of complications [6], but may prolong recovery—a particular disadvantage in children undergoing day-case surgery. Crean and colleagues found that premedication with atropine reduced significantly the incidence of airway complications, although desaturation occurred occasionally and induction time was not shortened [5]. Use of oxygen alone as
the carrier gas would delay the onset of desaturation during respiratory complications, but this effect might be offset by prolongation of induction time and increased incidence of complications in the absence of nitrous oxide [7, 8]. Van Heerden and colleagues showed that humidification of the inspired gas mixture was associated with fewer complications during induction with isoflurane. However, there were insufficient children in their study for any firm conclusion to be made about the value of this technique in paediatric practice [12].

Addition of carbon dioxide to inspired gases in order to accelerate induction of anaesthesia has been practised for many years [13]. A recent survey of anaesthetists in the United Kingdom revealed that 13% of respondents currently use carbon dioxide for this purpose [14]. However, the technique is not without hazard. Halothane may cause cardiac arrhythmias in the presence of hypercapnia, but this has not been demonstrated with isoflurane [7, 8].

End-tidal carbon dioxide partial pressures of between 9.0 and 11.6 kPa have been recorded in children breathing isoflurane after sedative premedication, without arrhythmias [9]. With our sampling site, a small degree of mixing of expired gases was unavoidable, so true end-tidal concentrations of carbon dioxide may have been somewhat greater than those recorded. However, no cardiac arrhythmia was observed in any patient. Interestingly, a child in group A developed a peak expired concentration of carbon dioxide equal to the greatest value recorded in group B (9.0%). This occurred during an episode of breath-holding, coughing and laryngospasm and was accompanied by severe desaturation.

The more rapid attainment of 5% inspired isoflurane in group B was not unexpected. Of greater importance was the marked reduction in the incidence and severity of complications when 5% carbon dioxide was added to the inspired mixture. Complications occurred in 8% of patients in group B—an incidence similar to that reported by other workers studying inhalation induction with halothane [2, 3, 10, 11]. The complications were minor, required no alteration in anaesthetic technique and were not associated with any change in \( \text{Sp}_{\text{O}_2} \), which remained greater than 85% in all children in group B. \( \text{Sp}_{\text{O}_2} \) values between 85 and 90% were recorded in three infants in group B, all in association with crying on arrival in the anaesthetic room. In each case, \( \text{Sp}_{\text{O}_2} \) increased rapidly with administration of the anaesthetic and cessation of crying.

Arterial saturation values less than 85% occurred only in group A (\( n = 4 \)) and were always associated with respiratory complications.

We conclude that, in small children, airway related complications may be common during inhalation induction with isoflurane and nitrous oxide and are not prevented by premedication with atropine. Addition of 5% carbon dioxide to the inspired gases significantly reduced the frequency and severity of these complications and provided a quality of induction similar to that achieved normally with halothane. The availability of carbon dioxide on the anaesthetic machine is not, of course, without potential hazard; however, with flow-limited carbon dioxide rotameters and adequate monitoring, we believe this is a safe technique.

REFERENCES

12. van Heerden PV, Wilson IH, Marshall FPF, Cormack JR. Effect of humidification on inhalation induction with

