USE OF CONTINUOUS POSITIVE AIRWAY PRESSURE IN PAEDIATRIC DENTAL EXTRACTION UNDER GENERAL ANAESTHESIA

D. SURESH, G. PURDY, A. P. WAINWRIGHT AND P. J. FLYNN

SUMMARY

In a controlled prospective study, we studied 150 grade ASA I children undergoing outpatient dental extraction under inhalation anaesthesia with a T-piece system allocated to three equal groups: a control group (0 cm H₂O CPAP), and two study groups receiving 2.5 or 5 cm H₂O of CPAP via a nasal mask. We found that the incidence and severity of oxygen desaturation were reduced significantly in the 5-cm H₂O CPAP group.

KEY WORDS
Anaesthesia: outpatient, dental Oxygen: pulse oximetry. Ventilation • continuous positive pressure breathing.

A decrease in arterial oxygen saturation by more than 10% has been demonstrated in children undergoing dental extraction under general anaesthesia with both inhalation and i.v. techniques of induction [1, 2]. This results predominantly from upper airway obstruction at the time of insertion of the dental prop and pack and during extractions. This obstruction may be accentuated in children of this age group by their tendency to rhinitis and hypertrophy of the adenoids and tonsils [3].

Nasal continuous positive airways pressure (CPAP) has been reported to increase oxygen saturation in the presence of measured oxygen desaturation and partial airway obstruction in adults and children, for example in obstructive sleep apnoea syndrome [4–6]. CPAP also exerts a beneficial effect on the functional residual capacity (FRC) [7–9] and the work of breathing [9].

This study was designed to measure oxygen saturation in children undergoing outpatient dental extractions, when 0, 2.5 or 5 cm H₂O of CPAP was added to a standard technique of inhalation nasal mask anaesthesia via a T-piece system.

PATIENTS AND METHODS

Following approval by the London Hospital Ethics Committee, we studied 150 children of ASA grade I, aged 1–14 yr, undergoing outpatient dental extraction under general anaesthesia. They were allocated to three groups: group A = 0 cm H₂O CPAP; group B = 2.5 cm H₂O CPAP; group C = 5 cm H₂O CPAP. The groups were studied in the sequence C, B and A and involved many anaesthetists, surgeons and trainees of varying grades, to negate the learning curve effect and to conform with our normal clinical practice. The range of ages encountered (group A 2–14 yr, group B 2–14 yr and group C 1–13 yr) reflected the occasional admission of patients at the extremes of this range during the period of study and was limited to the two patients concerned in each group (table I).

Measurement of oxygen saturation (SpO₂) commenced before anaesthesia using an Ohmeda Biox 111 BOC Health Care pulse oximeter, which has been shown to have an accuracy of ±2.4% in the 80–100% range [10]. Oxygen saturation was recorded continuously on a Gould TA 550 three-channel pen chart recorder. All patients were monitored with a Cardiorater ECG. Heart rate was recorded at 30-s intervals and incidence and duration of cardiac arrhythmias noted and recorded.

Anaesthesia was induced in patients in the...
supine position via the open end of the T-piece held close to the mouth and nose, using halothane in increasing concentrations up to 5% and 66% nitrous oxide in oxygen. When judged appropriate by the anaesthetist, a nasal mask (SEFAM, France) was applied and the halothane concentration decreased to 2%. The use of a nasopharyngeal airway was left to the discretion of the anaesthetists who were of varying grades and included supervised dental students and junior trainees in anaesthesia. The grade of the person performing dental extractions (which included supervised dental students) was noted.

The T-piece system had a wide-bore inspiratory tube and 4-litre reservoir bag. A CPAP level of 0 cm, 2.5 cm or 5 cm H₂O was applied with an adjustable Heidbrink valve. The fresh gas flow used was 9 litre min⁻¹ in children aged 1–7 yr and 12 litre min⁻¹ in children older than 7 yr, to ensure that the reservoir bag remained almost fully distended throughout the respiratory cycle [11, 12].

The SEFAM nasal mask has two oxygen portholes which were utilized for pressure monitoring and carbon dioxide sampling (fig. 1). Carbon dioxide was measured with a Datex Normocap carbon dioxide monitor and a pen chart recorder with a sampling rate of 150 ml min⁻¹. A Gould Statham P231D pressure transducer was used to measure CPAP and, consequently, the duration of gas tight seal at the mask during the ventilatory cycle. Both the Datex Normocap and Gould Statham transducer were calibrated according to the manufacturers’ instructions before each anaesthetic session. Airway pressure was recorded continuously on a Gould TA 550 three-channel pen chart recorder.

Surgery commenced when the depth of anaesthesia was judged to be adequate and key anaesthetic and surgical events were noted. Whenever desaturation in excess of 10% from baseline values occurred, surgery was interrupted until SpO₂ had improved to nearer baseline values following restoration of the airway.

Statistical analysis

Parametric data were analysed using an unpaired Student’s t test. Non-parametric 95% confidence intervals for median baseline and median least SpO₂ (%) were obtained for the three groups and a Mann–Whitney U test used to compare baseline oxygen saturation and peroperative desaturation. The incidence of cardiac arrhythmias was compared using a chi-square test. Three-way analysis of variance was performed to compare the groups and the grades of anaesthetists and surgeons for peroperative desaturation. P < 0.05 was accepted as statistically significant.

RESULTS

The three groups were comparable with regard to age and numbers of teeth extracted (table I), and race (table II).

<table>
<thead>
<tr>
<th>Age (yr) (mean (range))</th>
<th>Number of teeth extracted (mean (SEM))</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>6.3 (2–14)</td>
<td>3.9 (0.3)</td>
</tr>
<tr>
<td>Group B</td>
<td>6.5 (2–14)</td>
<td>3.4 (0.3)</td>
</tr>
<tr>
<td>Group C</td>
<td>5.7 (1–13)</td>
<td>3.4 (0.3)</td>
</tr>
</tbody>
</table>
TABLE II. Racial distribution of patients in groups A, B and C

<table>
<thead>
<tr>
<th>Group</th>
<th>Caucasian</th>
<th>Asian</th>
<th>Negro</th>
<th>Negro/Caucasian</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>26</td>
<td>22</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Group B</td>
<td>30</td>
<td>18</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Group C</td>
<td>31</td>
<td>16</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

There was a significant difference between groups with regard to oxygen desaturation, the incidence and severity of which was less in the 5-cm H$_2$O study group compared with the control group (fig. 2, table III). Oxygen desaturation occurred mainly during the following events: induction, application of mask, insertion of the prop and pack and during dental extractions. These episodes of hypoxemia resulted predominantly from partial upper airways obstruction during these events.

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VENTILATORY FREQUENCY WAS SIMILAR IN THE GROUPS, ALTHOUGH THE END-TIDAL CONCENTRATIONS OF CARBON DIOXIDE INCREASED SIGNIFICANTLY IN PATIENTS WHO RECEIVED CPAP (TABLE IV). THERE WAS NO SIGNIFICANT DIFFERENCE BETWEEN THE TWO STUDY GROUPS FOR THE PERCENTAGE OF TIME THAT CPAP WAS MAINTAINED (72% FOR GROUP B, 64% FOR GROUP C). TEMPORARY LOSS OF CPAP OCCURRED, AS ANTICIPATED, DURING INSERTION OF THE DENTAL PROP AND PACK AND JAW MANIPULATION.

The mean baseline heart rate in the three groups was similar. In all groups, the majority of patients displayed a mean increase in heart rate.

<table>
<thead>
<tr>
<th>Group</th>
<th>Heart rate (beat min$^{-1}$)</th>
<th>Ectopic beats (No. min$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>Increase</td>
<td>Decrease</td>
</tr>
<tr>
<td>Group A</td>
<td>89 (2.6)</td>
<td>41 (3.3)</td>
</tr>
<tr>
<td></td>
<td>(n = 50)</td>
<td>(n = 46)</td>
</tr>
<tr>
<td>Group B</td>
<td>99 (2.6)</td>
<td>35 (2.5)</td>
</tr>
<tr>
<td></td>
<td>(n = 48)</td>
<td>(n = 43)</td>
</tr>
<tr>
<td>Group C</td>
<td>101 (2.6)</td>
<td>33 (2.9)</td>
</tr>
<tr>
<td></td>
<td>(n = 50)</td>
<td>(n = 44)</td>
</tr>
</tbody>
</table>
during operation. In a small number of patients there was a reduction in heart rate, but none required treatment. There was no significant difference between the three groups with regard to the incidence or duration of arrhythmias (table V).

Three-way analysis of variance between the groups and grades of anaesthetist and surgeon, showed no significant difference (P = 0.89) for the incidence of desaturation (table VI).

**DISCUSSION**

Hypoxaemia during dental extraction under nasal mask anaesthesia is often rapid in onset, not always obvious clinically [1, 13-15], and reported to be a major contributory factor to death from dental anaesthesia [16]. Pulse oximetry provides an advance in monitoring by detecting small reductions in oxygen saturation and displaying trends [10, 17].

Historically, low inspired oxygen concentrations were used for dental extraction under inhalation general anaesthesia. Increasing the fractional inspired oxygen concentration (FIO2) to 0.3 reduced the incidence and severity of peroperative desaturation compared with an FIO2 of 0.2 or 0.25 [18], but it has been shown that a further increase in FIO2 to 0.5 does not improve peroperative oxygen saturation [19]. This led to the investigation of the value of nasal CPAP on peroperative oxygen saturation in this study.

In young children, airway closure occurs at lung volumes well above FRC, producing a relatively high intrapulmonary shunt [20, 21]. During general anaesthesia, when there is further reduction in FRC, this intrapulmonary shunt is exacerbated [20-22] and, together with the propensity for upper airway obstruction caused by rhinitis and lymphoid hypertrophy in this age group, there is greater tendency to hypoxia.

Several studies have suggested two mechanisms whereby CPAP may enhance gas exchange and oxygenation in these children. First, there is an increase in FRC proportional to the CPAP [7, 8]. Second, CPAP may overcome apnoea and partial soft tissue airway obstruction [6]. In addition, the application of CPAP may rectify breathing in children with irregular breathing patterns [23]. In this study the application of 5 cm H2O of CPAP resulted in a significant reduction in the incidence and severity of peroperative oxygen desaturation.

The increased ventilatory frequencies recorded during anaesthesia were consistent with similar studies in children receiving inhalation general anaesthesia with halothane [24].

The use of a pressure monitor in the circuit permitted attainment of the correct value of CPAP with a small fluctuation in pressure of ±1 cm H2O noted throughout the ventilatory cycle. Reductions in pressure within the circuit alerted the anaesthetist to malposition of the pack, whereas a loss of pressure variations suggested airway obstruction or apnoea, and allowed early detection and repositioning of the jaw or mask before significant desaturation occurred. Pressure monitoring is also essential to guard against the potential hazard of inadvertent application of excessive CPAP [25].

One consideration in choosing the most appropriate breathing system for anaesthesia is its effect on the work of breathing. It has been shown that, when airway pressure is kept constant with increasing CPAP, the inspiratory work performed by the subject is decreased [26-29]. The 4-litre reservoir bag, wide bore tubing and high fresh gas flows ensured that marked fluctuations in airway pressure did not occur. The system described in
this study for the application of CPAP would not, therefore, theoretically affect adversely the work of breathing, but may indeed reduce it.

Random allocation of patients in this study was impractical for several reasons, and the possibility of sequential error remains. Unlike a previous investigation [1], the grade of anaesthetist or surgeon was found to have no significant effect on peroperative oxygenation in either this or another study comparing an FI\textsubscript{O}\textsubscript{2} of 0.3 with an FI\textsubscript{O}\textsubscript{2} of 0.5 [19]. Surprisingly, the percentage incidence of hypoxaemic episodes for senior anaesthetists was twice that of junior trainees and dental surgeons seemed to contribute equally to these episodes (table VI). Although, on occasions, oxygen saturation decreased to as little as 80\%, obvious cyanosis was not reported by the anaesthetists or detected by the observers in any patient. This may have resulted from the close monitoring used for the purposes of this study, and underlines further the value of such practice in routine anaesthesia.

REFERENCES