Duration of Apnea in Anesthetized Infants and Children Required for Desaturation of Hemoglobin to 95%

The Influence of Upper Respiratory Infection

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Sixty-one patients ASA physical status 1–2 aged 1 month to 12 years undergoing elective surgery were included in the study. Anesthesia was induced via a mask with sevoflurane up to 5% and 66% nitrous oxide in oxygen. After paralysis with vecuronium (0.12 mg/kg iv), the trachea was intubated and the lungs were ventilated manually with 3% sevoflurane in oxygen until the end-tidal nitrous oxide decreased to less than 5%. Apnea was started by disconnecting the breathing circuit from the endotracheal tube. The time from the start of apnea to SpO\(_2\), of 95% was measured. Manual ventilation was reinstituted when SpO\(_2\) decreased to 95% and another set of vital signs was recorded. Twenty of 61 patients had symptoms of upper respiratory infection. The time to SpO\(_2\) of 95% correlated well with height, age, and body weight both by linear and non-linear regression analyses. The patients with symptomatic upper respiratory infection required less time for SpO\(_2\) to decrease to 95% compared to the asymptomatic children. We conclude that younger children require less time for SpO\(_2\) to decrease to 95%. The presence of upper respiratory infection is an increasing factor in the susceptibility of small children to hypoxemia. (Key words: Age factors. Anesthesia, pediatric. Hypoxemia. Infection, upper respiratory. Lung functional residual capacity. Monitoring: pulse oximetry. Oxygen saturation. Ventilation: apnea.)

PREVENTION OF HYPOXEMIA is of fundamental importance to anesthesiologists. For several reasons younger children are thought to be at greater risk of hypoxemia than are older children or adults. The functional residual capacity (FRC) expressed on a basis of weight is smaller in younger than in older children and adults,\(^1,2\) whereas oxygen consumption per unit body weight is greater.\(^3,4\) The time to the onset of hypoxemia during apnea is dependent on the balance between oxygen supply to and extraction from the circulating blood. Oxygen supply during apnea comes mainly from FRC and therefore will be less in patients with a smaller FRC. Additionally, the greater relative oxygen consumption in younger patients will deplete oxygen more rapidly. Thus, younger patients should be more susceptible than older children to the risk of hypoxemia during apnea.

The purpose of this study was to determine whether there was a relationship between the age and duration of apnea required for hemoglobin oxygen saturation to decrease to 95% in anesthetized children. The presence of symptoms of upper respiratory infection (URI) was also evaluated in terms of its influence on the duration of apnea required for hemoglobin oxygen saturation to decrease to 95%.

Materials and Methods

Sixty-one patients ASA physical status 1 or 2 aged 1 month to 12 years undergoing elective surgery were included in the study. They were all free of cardiovascular abnormalities. The approval of the institutional ethical committee and informed consent of the parents were obtained.

Prenesthetic evaluation included the recent history and the present symptoms of URI. When rhinorrhea and/or congestion were the only signs, an effort was made to differentiate the chronic course of allergic rhinitis from the early stage of URI.

Diazepam (0.5 mg/kg, maximum 10 mg) and famotidine (1 mg/kg, maximum 20 mg) were given rectally 30 min prior to anesthesia.

Anesthesia was induced via a mask with sevoflurane up to 5% and 66% nitrous oxide in oxygen. After a catheter was inserted into a peripheral vein, patients were paralyzed with vecuronium 0.12 mg/kg and nitrous oxide was discontinued. After tracheal intubation, the lungs were ventilated manually with sevoflurane 3% in oxygen until the end-tidal nitrous oxide decreased to less than 5%. End-tidal F\(_{\text{CO}_2}\) was maintained between 25–40 mmHg. After recording the basal vital signs, apnea was begun by disconnecting the breathing circuit from the endotracheal tube. The time from the start of apnea to SpO\(_2\) of 95% was measured using a stopwatch. Manual ventilation was resumed when SpO\(_2\) decreased to 95% and another set of vital signs was recorded.

ECG, heart rate, blood pressure, and rectal temperature were monitored. Arterial hemoglobin oxygen saturation (SpO\(_2\)) was monitored via a fingertip probe applied to the left thumb with a pulse oximeter (Nellcor N-200,
Hayward, CA) adjusted to rapid update mode (3-s averaging). Inspired and end-tidal concentrations of oxygen, carbon dioxide, nitrous oxide, and sevoflurane were measured and displayed digitally with Anesthetic Gas Monitor Type 1304 (Brüel & Kjaer, Denmark). All measurements were completed prior to the start of surgery. The recording was done by one of the authors who was not aware of the patient’s characteristics.

Values are presented as the mean ± SD. The demographic and hemodynamic data were analyzed with Student’s t test (unpaired and paired). The relationship between the time from the start of apnea to SpO₂ of 95% versus age, height, and body weight was analyzed by linear and non-linear regression analysis. P < .05 was considered to indicate statistical significance.

**Results**

Of 61 patients studied, 20 had one or more apparent symptoms of URI, such as rhinorrhea, congestion, coughs, or fever and were classified as symptomatic (group 2). The remaining 41 were classified as asymptomatic group (group 1). Data were analyzed in groups with and without symptoms of URI separately and also combined as a whole.

There were no significant differences in age, height, weight, hemoglobin concentration, and rectal temperature between group 1 and group 2 (table 1). The rectal temperature was lower than 37.6° C in all patients.

All patients had an SpO₂ of 100% at the start of apnea. Figure 1 depicts the correlation between the age and height versus the time to SpO₂ 95%. Linear regression lines for group 2 showed that in the symptomatic patients a shorter duration of apnea compared to that in the asymptomatic patients was required for SpO₂ to decrease to 95%. Non-linear regression analysis did not improve the correlation (data not shown).

After re-institution of manual ventilation, SpO₂ values still declined in most patients by 1–3% before returning to 100%. The mean nadir reached after apnea was 93.5 ± 1.0% (minimum 90%).

No arrhythmias or severe bradycardia were observed throughout the procedure. Heart rate decreased slightly but significantly at the end of apnea in group 1 (from 134.3 ± 23.0 to 130.2 ± 22.1 bpm, P < .05), but the decrease did not reach the statistical significance in group 2 (from 139.0 ± 19.0 to 136.1 ± 18.6 bpm). Systolic and diastolic blood pressure did not change during apnea in either group.

There were no differences in end-tidal P<sub>CO₂</sub> between groups at both the start and the end of apnea. End-tidal P<sub>CO₂</sub> was 30.8 ± 4.7 mmHg before apnea and increased to 41.3 ± 6.9 mmHg (P < .05 vs. pre-apnea) immediately after apnea, when analyzed as a combined group.

**Table 1. Demographic Data of Patients**

<table>
<thead>
<tr>
<th></th>
<th>Group 1</th>
<th>Group 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>41</td>
<td>20</td>
</tr>
<tr>
<td>Sex (M/F)</td>
<td>22/19</td>
<td>11/9</td>
</tr>
<tr>
<td>Age (y)</td>
<td>3.5 ± 3.6</td>
<td>2.4 ± 2.4</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>89.6 ± 25.8</td>
<td>82.2 ± 16.8</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>14.2 ± 8.1</td>
<td>11.5 ± 4.4</td>
</tr>
<tr>
<td>Hemoglobin (g/dl)</td>
<td>12.6 ± 1.2</td>
<td>12.5 ± 1.0</td>
</tr>
<tr>
<td>Rectal temperature (° C)</td>
<td>37.1 ± 0.4</td>
<td>37.2 ± 0.3</td>
</tr>
</tbody>
</table>

Group 1 = asymptomatic patients; group 2 = patients with symptoms of upper respiratory infection. There were no significant differences between groups.

![Fig. 1. Relationship between T<sub>95</sub> (s) (time from the start of apnea to SpO₂ 95%) versus age (y) (A) and height (cm) (B). Open circles = asymptomatic patients; closed circles = symptomatic patients. Solid and dotted lines indicate linear regression lines for the asymptomatic and the symptomatic group, respectively. T<sub>95</sub> was related to age and height as follows: Asymptomatic group: T<sub>95</sub> (s) = 16.47 × age (y) + 117.0 (r = 0.91); T<sub>95</sub> (s) = 2.17 × height (cm) − 21.2 (r = 0.91). Symptomatic group: T<sub>95</sub> (s) = 13.47 × age (y) + 92.6 (r = 0.80); T<sub>95</sub> (s) = 1.92 × height (cm) − 33.3 (r = 0.81).](http://anesthesiology.pubs.asahq.org/pdfaccess.ashx?url=/data/journals/jasa/931817/)
Discussion

This study shows clearly that younger children require less time than do older children for desaturation of hemoglobin to 95% to occur.

FRC in children correlates well with height, weight, and age without a significant difference between sexes.\textsuperscript{1,2,5} The ratio of FRC to body weight is reported to increase with age.\textsuperscript{1,2} In a study of anesthetized children, Thorsteinsson et al.\textsuperscript{1} reported that FRC was 17 ± 4 ml/kg in infants, whereas the value in children older than 1 year was 24 ± 6 ml/kg. Similarly, Gerhardt et al.\textsuperscript{2} showed that FRC per kilogram of weight is less in neonates than in larger infants. Oxygen consumption expressed on a weight basis is known to be greater in younger than in older children.\textsuperscript{3,4} Reduced oxygen supply from the small FRC combined with increased oxygen demand will sufficiently explain the shorter duration of apnea for hemoglobin desaturation to occur in younger than in older children.

Since the accuracy of \( S_{O_2} \) and its good correlation with \( S_{aO_2} \), are well established,\textsuperscript{6} blood gas analysis was not performed in order to minimize invasive maneuvers. For the safety of young and growing patients and considering the possibility of a further decrease of oxygen saturation, the limit of apnea was set to an \( S_{O_2} \) of 95% in our study, although a 90% is a more common limit.\textsuperscript{7,8} The lowest value of \( S_{O_2} \) observed in our study was 90% after the reestablishment of ventilation. A further decrease in \( S_{O_2} \) after the reestablishment of ventilation has also been reported by other authors and explained by the time delay for the more desaturated alveolar capillary blood to reach the peripheral circulation.\textsuperscript{8,9}

The presence of URI symptoms is one of the frequent causes to postpone an elective surgery in children for fear of increased airway irritability, which might lead to laryngospasm or bronchospasm during anesthesia\textsuperscript{10} or other perioperative complications including postoperative oxygen requirements. In this study the URI-symptomatic group demonstrated a shorter duration of apnea compared to that of the asymptomatic group. Since body temperature was identical in both groups and respiratory work was absent with paralysis, the difference of oxygen consumption between groups is not likely to be the cause. Spirometric and functional changes have been reported in the patients with URI.\textsuperscript{11,12} In the study of spirometry in children, Collier et al.\textsuperscript{11} reported a decrease in functional vital capacity without a change in total lung capacity and a decrease in flows at most lung volumes in children with URI, suggesting earlier airway closure. Pulmonary changes, such as reduced FRC or increased airway closure at the level of FRC, may be present in the symptomatic group, and these changes would reduce the oxygen reserve in the lungs. As another possibility, an increase in the alveolar to arterial oxygen partial pressure difference may be present in these patients. If true, although \( S_{O_2} \) was 100% in both groups, \( P_{aO_2} \) and oxygen content of the arterial blood might have been less in the symptomatic patients at the start of apnea and therefore less time for desaturation would be required. The shorter duration required in the symptomatic patients might provide another scientific basis that more caution should be used in the perioperative care of the patients with URI symptoms.

In conclusion, the time required for \( S_{O_2} \) to decrease from 100% to 95% was less in younger children than in older children and, further, was less in children with signs of URI than in those symptom-free.

References