Pharyngeal Oxygen Insufflation During AirTraq Laryngoscopy Slows Arterial Desaturation in Infants and Small Children

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BACKGROUND: The extent to which insufflation of oxygen into the posterior pharynx during laryngoscopy prolongs adequate saturation in infants and small children remains unknown. Therefore, we compared oxygen saturation over time in preoxygenated small children with and without posterior pharynx oxygen insufflation.

METHODS: After induction of anesthesia with sevoflurane and propofol, infants and small children were preoxygenated with 100% oxygen for 3 minutes. An AirTraq laryngoscope size 0 or 1 with an appropriately sized cuffed endotracheal tube positioned in the side channel was prepared. Oxygen tubing was connected to the endotracheal U-shaped tube. However, oxygen at a flow of 4 L/min was provided only to half of the randomly selected participating patients. The trachea was intubated, the tube cuff was inflated, and the laryngoscope was removed from the mouth. The oxygen tubing was disconnected from the endotracheal tube and left exposed to ambient air until oxygen saturation decreased to 95%. Thereafter, patients’ lungs were manually ventilated with 100% oxygen until SpO2 returned to 100%. Subsequent anesthetic management was at the discretion of the attending anesthesiologist.

RESULTS: Laryngoscopy took a median of 60 (Q1–Q3, 40–90) seconds. The mean time to 95% oxygen saturation was (mean ± SD) 166 ± 47 seconds in the oxygen insufflation group and 131 ± 39 seconds in small children without insufflation. Oxygen insufflation prolonged the mean time for saturation to decrease from 100% to 95% by an estimated 35 (95% confidence interval, 10–60) seconds, P = 0.01.

CONCLUSIONS: Adding posterior pharyngeal oxygen insufflation to conventional preoxygenation prolonged the period of adequate oxygen saturation in infants and small children by an amount that is potentially clinically important. (Anesth Analg 2016;122:1153–7)

All patients having general endotracheal anesthesia at least a brief period of apnea during intubation. Short periods of apnea are usually well tolerated in adults, but even uncomplicated intubation can lead to desaturation in infants and small children because they have higher oxygen demands and a smaller functional residual capacity (FRC) than adults.1

Preoxygenation delays arterial desaturation in unventilated adults with a patent airway.2 Preoxygenation replaces nitrogen in the lungs with oxygen, thus increasing oxygen reserves of the body.3 During apnea, oxygen is extracted from the FRC into the blood. Because carbon dioxide has a greater solubility in the blood, fewer carbon dioxide molecules are released into the lungs. Oxygen is consequently drawn into the lungs during oxygen insufflation because of the subatmospheric pressure in the alveoli.4

The effective period of preoxygenation can possibly be extended to include intubation when oxygen is insufflated into the posterior pharynx. A recently developed laryngoscope (AirTraq, Prodol Meditec S.A., Vizcaya, Spain) includes a channel for an endotracheal tube and thus allows insufflation of oxygen through the tube during laryngoscopy.

The extent to which insufflation during laryngoscopy prolongs the tolerable period of apnea after full preoxygenation in small children remains unknown. Therefore, we compared oxygen saturation over time in preoxygenated infants and small children who were intubated with and without posterior pharynx oxygen insufflation. Specifically, we tested the hypothesis that oxygen saturation over time is better maintained in small children when oxygen is insufflated into the posterior pharynx during intubation.

METHODS

With IRB approval from the Medical University of Vienna, written consent for participation in this study was obtained from parents the day before surgery. The trial was registered at ClinicalTrials.gov (NCT01664234).

Participation was restricted to infants and small children aged 0 to 2 years scheduled for cochlea implants, for congenital deafness, for cleft lips and/or palate reconstructions, or for surgery for other congenital head and face abnormalities, including eye surgery (glaucoma or congenital cataract). All were scheduled for general anesthesia with endotracheal intubation. Children with heart abnormalities or lung diseases were excluded, as were patients with ASA physical status ≥III.

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Pharyngeal Oxygen Insufflation Slows Desaturation During Intubation in Small Children

Protocol

Participating infants and small children were premedicated with 0.5 mg/kg midazolam in the preoperative unit and thereafter brought to the operating room. After conventional monitors were applied, anesthesia was induced by inhalation of 60% nitrous oxide in oxygen and 5% to 7% sevoflurane.

An IV catheter was inserted once effective manual ventilation was established and corneal reflexes were lost. Nitrous oxide was then discontinued, and manual ventilation was continued with 100% oxygen in 5% to 6% sevoflurane for 3 minutes. Simultaneously, 2 to 4 mg/kg propofol and 3 μg/kg fentanyl were given IV, which reliably arrested ventilation.

Participants were randomly assigned (1:1 without stratification) to intubation with or without insufflation of oxygen at 4 L/min. Randomization was based on computer-generated codes that were maintained in sequentially numbered opaque envelopes. An AirTraq laryngoscope size 0 or 1 with an appropriately sized cuffed endotracheal U-shaped tube positioned in the side channel was prepared by an investigator. In each case, tubing was connected to the endotracheal tube (Fig.1). However, oxygen was provided only if so designated per randomization. To maintain blinding, the suction flowmeter was turned to “high” to obscure the sound of insufflated oxygen and the flowmeter obscured. Thus, the attending anesthesiologist was entirely blinded to the randomization. Continuous positive airway pressure was not provided during intubation.

The attending physician inserted the endotracheal tube through the vocal cords under direct vision, the tube cuff was inflated, and the laryngoscope was removed from the mouth. The oxygen tubing was then disconnected from the endotracheal tube and was left exposed to ambient air until oxygen saturation decreased to 95%. Thereafter, the endotracheal tube connected to the circle system, and patients’ lungs were manually ventilated with 100% oxygen until \( \text{SpO}_2 \) returned to 100%, and a normal end-tidal \( \text{PcO}_2 \) tracing was confirmed. Subsequent anesthetic management was at the discretion of the attending anesthesiologist.

Had the oxygen saturation reached 95% during intubation and the endotracheal tube not yet passed the vocal cords, the case would be deemed a failure and the child would have been mask ventilated until another intubation method was implemented.

Measurements

Demographic and morphometric characteristics were recorded, along with types of surgery. Cormack and Lehane grade was evaluated after initial insertion of the AirTraq laryngoscope.

Oxygen saturation was measured with a pulse oximeter (Masimo Cooperation, Irvine, CA) positioned on the index finger. Signal averaging was set to 0 seconds. Saturation was recorded with the patient breathing room air just before anesthetic induction and again after 3 minutes of manual ventilation with 100% oxygen. Insertion of the laryngoscope into the mouth was considered elapsed time 0. Oxygen saturation was thereafter recorded at 10-second intervals until the saturation was ≤95%. Time of intubation was recorded, as was the time ventilation restarted.

Statistical Analysis

Analyses were completed using the modified intent-to-treat principle and thus included all randomly assigned patients who began tracheal intubation. We assessed balance of the randomly assigned groups on potentially confounding variables using absolute standardized difference (ASD), defined as the absolute difference in means or proportions divided by the pooled SD. Any variables with ASD greater than the value given in the following equation would be considered imbalanced and were adjusted for in the analyses.

\[
\text{ASD} > 1.96 \times \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}
\]

We estimated the effect of oxygen insufflation on time between laryngoscope insertion and reaching oxygen saturation of 95% by using a 2-tailed \( t \) test. This method was appropriate because the residuals were normally distributed (Shapiro-Wilk test for normality, \( P = 0.51 \)), no observations were censored, and no baseline covariates were imbalanced. We also plotted Kaplan-Meier curves to estimate the fraction of patients remaining with a saturation >95% over time, testing separation of curves using a log-rank test.

For designing the study, we considered 15 seconds to be a clinically important difference. Based on the expected SD of 15 seconds, 24 children were randomly assigned to each group to achieve 92% power at the 0.05 significance level.

RESULTS

Forty-eight children were enrolled in this trial, with 24 randomly assigned to each group. Baseline characteristics, hemodynamic management, and types of surgery were similar in each group (Table 1).

One child assigned to receive oxygen insufflation was never successfully intubated because the tube could not be advanced. Because intubation was attempted, this child was...
included in the analyses and assigned the lowest saturation observed in the study population.

No baseline characteristics were adjusted for in the analyses because none was considered imbalanced between groups. All children assigned to the study completed the study. Individual desaturation curves for all participants are shown in Figure 2.

Laryngoscopy and intubation took a median of 60 (Q1–Q3, 40–90) seconds in all patients. The duration was 50 (40–90) seconds in the insufflation patients and 60 (40–80) seconds in the control patients. The mean time to 95% oxygen saturation was 166 ± 47 seconds in the oxygen insufflation group and 131 ± 39 seconds in the control group. Oxygen insufflation increased the mean time to 95% saturation by an estimated 35 seconds (95% confidence interval, 10–60), \( P = 0.01 \).

Figure 3 shows Kaplan-Meier estimates of the percentage of small children with oxygen saturation exceeding 95% over time for small children given oxygen insufflation and small children given routine therapy. Infants and small children randomly assigned to posterior pharynx oxygen insufflation took significantly longer to desaturate to 95% than those who were simply preoxygenated (\( P < 0.001 \), log-rank test).

**DISCUSSION**

Our primary result is that oxygen insufflation prolongs the period of adequate oxygen saturation by at least 10 seconds during intubation, but on average by a half-minute. This prolongation was not only statistically significant (\( P = 0.01 \)), but clinically important in that an additional half-minute to secure the airway might be critical in some infants and children, especially those such as we included who had congenital head or face abnormalities that are often associated with difficult airways.\(^5,6\)

Holmdahl\(^2\) introduced the concept of apneic diffusion of oxygen in 1956. During apnea, oxygen is extracted from the lungs into the blood to maintain metabolism. Because carbon dioxide is highly soluble in blood, most carbon dioxide generated during apnea is retained in the circulation, with little being added to the alveolar space in adults. Simultaneously, about 250 mL/min oxygen is extracted from the lungs. Subatmospheric pressure is therefore established in the alveoli, and fresh oxygen from the pharynx is drawn en masse into the lungs, thus maintaining arterial oxygenation.\(^2\)

The key to apneic oxygenation is that the FRC of the lungs must be mostly filled with oxygen when apnea starts. Otherwise, nitrogen rapidly accumulates in the lungs as oxygen is absorbed into the bloodstream, preventing development of subatmospheric alveolar pressure that pulls fresh gas from pharynx into the lungs.\(^2,7\) Thus, the duration of apnea without desaturation depends on preoxygenation time, FRC of the lungs, and oxygen consumption.\(^3\) Pediatric patients, especially infants, have smaller FRC in relation to the closing volume than adults and a relatively greater oxygen consumption.\(^8,9\) Thus, the time to critical desaturation, with or without supplemental oxygen, is considerably shorter in small children than adults.\(^1\)

### Table 1. Patient Baseline and Demographic Characteristics

<table>
<thead>
<tr>
<th>Factor</th>
<th>Oxygen (( n = 24 ))</th>
<th>Control (( n = 24 ))</th>
<th>ASD*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (mo)</td>
<td>11 ± 8</td>
<td>13 ± 10</td>
<td>0.27</td>
</tr>
<tr>
<td>Female (%)</td>
<td>12 (50)</td>
<td>10 (42)</td>
<td>0.17</td>
</tr>
<tr>
<td>Baseline oxygen saturation (%)</td>
<td>99 ± 1</td>
<td>99 ± 1</td>
<td>0.04</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>8.6 ± 2.8</td>
<td>9.5 ± 3.1</td>
<td>0.29</td>
</tr>
<tr>
<td>Systolic blood pressure (mm Hg)</td>
<td>84 ± 18</td>
<td>92 ± 18</td>
<td>0.46</td>
</tr>
<tr>
<td>Diastolic blood pressure (mm Hg)</td>
<td>44 ± 11</td>
<td>51 ± 13</td>
<td>0.53</td>
</tr>
<tr>
<td>Heart rate (bpm)</td>
<td>139 ± 19</td>
<td>130 ± 15</td>
<td>0.56</td>
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<tr>
<td>Cormack and Lehane grade 2</td>
<td>0 (0)</td>
<td>1 (4)</td>
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<tr>
<td>Procedure type</td>
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</tr>
<tr>
<td>Cleft lip or cleft palate</td>
<td>6 (25)</td>
<td>7 (29)</td>
<td></td>
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<tr>
<td>Cochlea implant</td>
<td>3 (13)</td>
<td>6 (25)</td>
<td></td>
</tr>
<tr>
<td>Other congenital craniofacial abnormalities</td>
<td>15 (63)</td>
<td>11 (46)</td>
<td></td>
</tr>
</tbody>
</table>

*ASA defined as the absolute difference in proportions or means divided by the pooled SD. Any characteristics with ASD > 0.57 (i.e., 1.96 \( \sqrt{\frac{1}{24} + \frac{1}{24}} \) were considered imbalanced and adjusted for in the analyses.

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Figure 2. Oxygen saturation over time by treatment group.

Figure 3. Kaplan-Meier estimates of the percentage of small children with oxygen saturation exceeding 95% over time for small children given oxygen insufflation and small children given routine therapy.
Pharyngeal oxygen insufflation slows desaturation during intubation in small children.

Three minutes of preoxygenation is sufficient to largely fill the lungs with oxygen, thus providing 8 minutes of apnea without desaturation in healthy adults. Three minutes of preoxygenation also appears sufficient in children; for example, Videira et al. showed that 3 minutes of preoxygenation maintains adequate SpO₂ longer than just 1 minute of preoxygenation in children. Thus, we used 3 minutes of preoxygenation in our patients.

We used AirTraq laryngoscopes to provide oxygen at a rate of 4 L/min to the posterior pharynx during intubation and to perform laryngoscopy under direct vision. Four liters per minute presumably keeps oxygen partial pressure in the pharynx near 100%. However, we did not test other insufflation flow rates nor did we test other insufflation systems, although it seems likely that almost any system that delivers oxygen to the posterior pharynx will similarly prevent desaturation. All our patients had normal cardiopulmonary reserve. Presumably, oxygen insufflation would also be beneficial in patients with compromised lungs, but the relative and absolute benefits cannot be predicted from our data.

That intubation took a long time (50–60 seconds) in our patients was an expected consequence of including patients who had syndromes that compromised laryngoscopy. However, intubation time per se did not influence our results because pharyngeal oxygen was provided throughout, and, per protocol (with consent and IRB approval), ventilation was delayed in all patients until hemoglobin saturation reached 95%. The desaturation times, even in patients not given pharyngeal oxygen, was twice the intubation period. Thus, faster intubation would have simply prolonged the time between intubation and reoxygenation but presumably would not have much changed the overall time from induction to desaturation.

Pharyngeal oxygen is unlikely to provide any substantive value during a typical 15-second intubation. This is to be expected because airway adjuvants offer little advantage during straightforward intubations. The question is whether a particular approach will help when intubation time is prolonged; our study was designed to mimic prolonged intubation. We only evaluated pharyngeal oxygen administration with the AirTraq. However, it seems likely that pharyngeal oxygen will be beneficial during prolonged intubation situations regardless of how it is delivered.

In summary, adding posterior pharyngeal oxygen insufflation during laryngoscopy to conventional preoxygenation prolonged the period of adequate oxygen saturation in infants and children by an average of 30 seconds. Oxygen insufflation is technically easy and provides a clinically important benefit. Thus, the approach seems well worth considering, especially in infants and small children at risk of being difficult to intubate.

DISCLOSURES

Name: Marita Windpassinger, MD.
Contribution: This author helped conduct the study.
Attestation: Marita Windpassinger approved the final manuscript.
Name: Olga Plattner, MD.
Contribution: This author helped design the study, conduct the study, and write the manuscript.
Attestation: Olga Plattner has seen the original study data, reviewed the analysis of the data, and approved the final manuscript.
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REFERENCES