Comparison of Efficacy of Preoxygenation by Conventional Method vs Conventional Plus Supplementation via Nasal Prongs at Two Different Flow Rates

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ABSTRACT

Aim: To compare the efficacy of preoxygenation by a commonly used conventional method of preoxygenation, that is, tidal volume breathing of 100% oxygen (O2) for 3 minutes, with preoxygenation with the conventional method and supplementary O2 supply via nasal prongs at two different flow rates.

Objectives: Primary objective evaluation of EtO2 following three different methods of preoxygenation, that is,

• 3 minutes of tidal volume breathing through a closed circuit and a well-fitting anesthesia face mask with 100% O2 at a flow rate of 12 L/minutes.
• 3 minutes of above plus supplementary O2 supply via nasal prongs at 3 L/minute.
• 3 minutes of above plus supplementary O2 supply via nasal prongs at 10 L/minute.

Secondary objective: To evaluate patient comfort using the three different preoxygenation techniques.

Materials and methods: In this prospective, observational, comparative cross-over study 110 patients were included. Each participant fulfilling the inclusion criteria then underwent three different methods of preoxygenation, that is,

• 3 minutes tidal volume breathing through a closed circle system with a well-fitted anesthesia face mask and valve completely open at a flow rate of 12 L/minute.
• 3 minutes of the above plus supplementary O2 via nasal prongs at 3 L/minute.
• 3 minutes of the above plus supplementary O2 via nasal prongs at 10 L/minute.
• The patients were asked to assess the comfort levels associated with each method.

Results: There was a statistically significant difference from baseline EtO2 with each of the methods (p < 0.001), implying all three methods increased the O2 reserve in the lung when compared with the baseline levels. Among the methods, method A produced 3.77 times higher EtO2 levels than method B [95% CI (2.54, 5.006) and p < 0.001]. Method C EtO2 levels are 10.26 times > method B [95% CI (11.22, 9.298) and p < 0.001] and 6.48 times higher than EtO2 of method A (95% CI (5.72, 7.24) and p < 0.001), implying method C produced best preoxygenation amongst all the methods.

Conclusion: Preoxygenation with the conventional method at 12 L/minute and conventional method supplemented with the nasal cannula at 3 L/minutes and 10 L/minute is efficacious in providing preoxygenation. The use of a nasal cannula at a flow rate of 3 L/minute, along with conventional preoxygenation, can cause a reduction in EtO2 as compared to conventional method alone. Preoxygenation is enhanced by nasal cannula at 10 L/minute, but the same should be titrated against the comfort of the patient. Nasal prongs are available in most patient care areas; therefore, this simple, noninvasive, inexpensive technique could be routinely incorporated with airway management at a flow rate of 10/minute to enhance preoxygenation.

Keywords: End-tidal oxygen, Nasal prongs, Preoxygenation.

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INTRODUCTION AND BACKGROUND

Preoxygenation before general anesthesia and tracheal intubation is an essential step to increase oxygen (O2) reserves in the lung and further delay hypoxemia during apnea if intubation. The goal of preoxygenation is to increase the...
We conducted a prospective, observational, cross-over study after obtaining institutional review board (IRB) approval and written informed consent from the volunteers. Standard monitoring equipment was attached to the participant and baseline EtO₂ levels of each participant were noted by asking the participant to breathe into an exhalation device connected by a sampling line to the EtCO₂ module of the multiparameter monitor. Each participant then underwent three different methods of preoxygenation, that is, 3 minutes of tidal volume breathing through a closed circle system with a well-fitted anesthesia face mask and valve completely open (method A), 3 minutes of above plus supplementary O₂ via nasal prongs at 3 L/minute (method B), 3 minutes of above plus supplementary O₂ via nasal prongs at 10 L/minute (method C) (Figs 1 to 3 ). Preoxygenation was conducted by an anesthesiologist with the participant in the supine position. The sequence of the three methods was randomized by the sealed envelope technique so that the order of one participant was completely different from another participant.

The primary outcome of our study was EtO₂ concentration which was measured at the end of each method of preoxygenation. EtO₂ measurement was done by asking the participant to exhale his/her first breath following 3 minutes of preoxygenation into a device to which a gas sampling line was attached.

We aimed to compare the efficacy of preoxygenation by a commonly used conventional method of preoxygenation, that is, tidal volume breathing of 100% O₂ at 12 L/minute for 3 minutes through a closed circuit vs preoxygenation as above, along with supplementary O₂ supply via nasal prongs at 3 L/minute (method B), 3 minutes of above plus supplementary O₂ via nasal prongs at 10 L/minute (method C) (Figs 1 to 3 ). Preoxygenation was conducted by an anesthesiologist with the participant in the supine position. The interval between the onset of apnea and the time required for SpO₂ to reach 90% is defined as the safe duration of apnea. It depends on the patient’s O₂ reserve as well as O₂ consumption. In healthy adults with 5.5 minutes of preoxygenation safe duration of apnea is 6.9 minutes after 100% O₂, 5 minutes after 80%, and only 1 minute with room air.

Conventionally described methods of preoxygenation are breathing 100% O₂ at tidal volume at an O₂ flow rate of at least 10 L/minute for 3 minutes through a well-fitting anesthesia face mask. Recent studies have shown that adding a supplementary O₂ supply via nasal cannula at 10 L/minute causes better preoxygenation by utilizing the nasopharynx as a reservoir space, especially in clinical situations like obesity, difficult mask ventilation, etc. Measurement of end-expiratory O₂ content gives an estimate of the degree of denitrogenation and therefore the adequacy of preoxygenation. We aimed to compare the efficacy of preoxygenation by a commonly used conventional method of preoxygenation, that is, tidal volume breathing of 100% O₂ at 12 L/minute for 3 minutes through a closed circuit vs preoxygenation as above, along with supplementary O₂ supply via nasal prongs at 3 L/minute and 10 L/minute. We also evaluated volunteer comfort using the three different preoxygenation techniques.

**Materials and Methods**

A total of 110 consenting healthy adult volunteers, 18–60 years of age, were included in the study. Those with a beard or any facial anomaly that was likely to affect the mask seal, obesity [body mass index (BMI > 30)], and pregnant volunteers were excluded. The sample size estimated was done from a similar study in which the mean EtO₂ was 79 ± 14 with the bag valve mask alone and 75 ± 8 with the bag valve mask with a nasal cannula. Our sample size was calculated as 111 and rounded off to 110.
Data were collected by observation method, which was controlled, structured, and nonparticipant type. The anesthesia workstation used was GE Care Station 650, consisting of a closed-circuit system, corrugated tubings, and a 3L reservoir bag. Patients in method A breathed O₂ at 12 L/minute with the adjustable pressure limiting (APL) valve kept fully open. The exhaled gases were carried via a gas sampling tubing to the GE Carescape 650 E-sCAiO respirator module (Fig. 4). This monitor samples gases at 250 mL/minute using a standard paramagnetic O₂ analyzer, measuring O₂ every 400 ms. It has an accuracy of ± 2% and was calibrated before the start of the study and used exclusively for the study. The exhalation device used was a disposable anesthesia circuit connector, which was attached to the gas sampling line.

The anesthesia circuit was primed with 100% O₂ by fully closing the APL valve, occluding the patient end, and flushing the O₂ valve till the reservoir bag filled up. The face mask (Anaesthesia mask Silicon, Airway® Surgical Ltd.) was applied as firmly as possible without causing much discomfort to the participant but with the intention of minimizing any leak. In methods B and C, participants were administered O₂ via the nasal cannula (Airway® Surgical Ltd.), attached to the auxiliary O₂ outlet, at a flow rate of 3 L/minute and 10 L/minute, respectively. Face masks and nasal cannula were removed, and participants were asked to exhale a single normal breath over 3–4 seconds without breathing room air into the exhalation device. The maximum value of the alveolar plateau recorded was considered the EtO₂. A 2–3-minute washout period was given with the participant breathing room air after each period of preoxygenation. To ensure adequate O₂ washout, EtO₂ was measured after each washout period. If the EtO₂ remained above baseline, the rest period was extended until baseline EtO₂ was achieved. The participant was also asked to assess the comfort levels associated with each method.

Statistical Methods
The purpose of our study was to compare the efficacy of preoxygenation by conventional method vs conventional plus supplementation via nasal prongs at two different flow rates. Statistical testing was done with Statistical Package for the Social Sciences (SPSS) 23.0 (SPSS Inc., Chicago, Illinois, USA). The investigator used mean and standard deviation for assessing the continuous variables like age and BMI. For the comparison of the baseline with methods A, B, and C, a paired student t-test was used. For the testing effectiveness, we used analysis of covariance (ANCOVA) (F-test), followed by Bonferroni post hoc test. For the comparison of methods and discomfort, the Chi-squared test was used. A p < 0.05 was considered statistically significant, whereas p < 0.001 was considered statistically highly significant (Fig. 5).

Observation and Results
Analysis of covariation (ANCOVA) was conducted to determine a statistically significant difference between methods A, B, and C on the EtO₂. The obtained F value from the table is 60.369 and is significant (F = 60.36, p < 0.001). Hence, there is a significant difference in the intervention among the groups (Table 1).
To determine the best among the three methods, the Bonferroni *post hoc* test was done (dependent variable—EtO₂).

Table 2 shows the Bonferroni *post hoc* test results, which show there is a significant difference between the methods used. Method A produced 3.77 times higher EtO₂ levels than method B (EtO₂ [95% confidence interval (CI) (2.54,5.006) and *p* < 0.001]). Method C EtO₂ levels were 10.26 times < method B (95% CI (11.22,9.298) and *p* < 0.001), and 6.48 times higher than EtO₂ of method A (95% CI (5.72,7.24) and *p* < 0.001), implying method C produced best preoxygenation amongst the three methods (Fig. 6).

The discomfort associated with each method was compared using the Chi-squared test. While methods A and B were not associated with any discomfort. In method C, 65.46% of the study population expressed discomfort.

**Discussion**

A nasal cannula, along with mask oxygenation, is recommended during preoxygenation, and a nasal cannula should be continued during apneic oxygenation. Our study aims to identify the effect of the presence of a nasal cannula during preoxygenation. Although supplemental O₂ via nasal cannula for preoxygenation before laryngoscopy would theoretically increase O₂ delivery, there are very few studies evaluating its efficacy, and most of the studies were based in emergency situations in intensive care units on patients requiring intubation.

In this prospective, comparative study, the efficacy of preoxygenation by tidal volume breathing with 100% O₂ at 12 L/minute for 3 minutes vs tidal volume breathing plus supplementation via nasal prongs at 3 L/minute and 10 L/minute was studied.

The baseline EtO₂ with room air was 16.41 (± 1.0) while the three methods produced EtO₂ of 73.45 (± 6.40), 69.67 (± 8.02), and 79.94 (± 6.41), respectively. The EtO₂ values, following preoxygenation, were higher than the baseline values in all three methods of preoxygenation, indicating that preoxygenation definitely increases the O₂ reserves in the body. Method C produced the highest end-tidal O₂.

**Table 1:** Comparison of EtO₂ of Method A, B, and C by a generalized linear model (ANCOVA)

<table>
<thead>
<tr>
<th>Method of preoxygenation</th>
<th>Mean EtO₂</th>
<th>Standard deviation</th>
<th>F</th>
<th><em>p</em>-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method A</td>
<td>73.46</td>
<td>6.404</td>
<td>61.19</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Method B</td>
<td>69.68</td>
<td>8.023</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Method C</td>
<td>79.94</td>
<td>6.415</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 2:** Bonferroni *post hoc* test results

<table>
<thead>
<tr>
<th>Paired differences</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>Standard error mean</th>
<th>95% confidence interval of the difference</th>
<th>t</th>
<th>Degree of freedom</th>
<th>Significance two-tailed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method B Method A</td>
<td>3.77477</td>
<td>6.54729</td>
<td>0.62144</td>
<td>2.54322 5.00333</td>
<td>6.074</td>
<td>110</td>
<td><em>p</em> &lt; 0.001</td>
</tr>
<tr>
<td>Method C Method B</td>
<td>-10.26126</td>
<td>5.11986</td>
<td>0.48596</td>
<td>-11.22431 -9.29821</td>
<td>-21.116</td>
<td>110</td>
<td><em>p</em> &lt; 0.001</td>
</tr>
<tr>
<td>Method C Method A</td>
<td>6.48649</td>
<td>4.03815</td>
<td>0.38328</td>
<td>5.72691 7.24607</td>
<td>16.923</td>
<td>110</td>
<td><em>p</em> &lt; 0.001</td>
</tr>
</tbody>
</table>
concentration when compared to the other two methods. It is a well-established fact that preoxygenation improves the O2 reserve in the lung, and our study also has similar findings.2,3,12,13

McQuade et al., in their study with bag-mask alone and bag-mask with the nasal cannula at 0 L/minute (66 ± 10), and 5 L/minute (74 ± 8), noted that EtO2 with nasal cannula at 0 and 5 L/minute lower when compared with bag-valve-mask (BVM) (84 ± 9) and the lowest values were observed with nasal cannula alone at 0 L/minute. This is similar to our study, where methods A and B produced EtO2 values of 73.45 (±6.40), and 69.67 (±8.02), respectively. The reason for the reduced EtO2 in method B might be that the concurrent presence of a nasal cannula, despite a flow of 3 L/minute introduced a leak to the intended tight fit of a BVM facemask. This leak allowed the entrainment of room air, thereby diluting the fraction of inspired O2.14

Hayes-Bradley et al., in their study to measure the efficacy of supplemental nasal cannula O2 with conventional BVM with or without a simulated face mask leak, kept the BVM flow rate of 15 L/minute and the nasal cannula flow rate of 10 L/minute.9 They used a 16 Fr nasogastric tube to create a simulated leak. They found out that, with the mask leak, supplemental nasal cannula at 10 L/minute improved BVM EtO2 (41 (±7) to 66 (±8)), but the EtO2 values never reached the levels of BVM without a mask leak (79 ± 14). These findings differ from our study, where we obtained a higher EtO2 value with method C when compared to methods A (73.45 (±6.40)) and B (69.67 (±8.02)). This could be because, in their study, the leak was purposely created with the use of two nasogastric tubes, and an additional leak could have occurred with the application of the nasal cannula, causing lesser EtO2 than the bag mask alone method.4,5

In our study, 100% of participants tolerated the high flow through a nasal cannula, but 65.4% of the patients expressed discomfort with the use of a nasal cannula at 10 L/minute as compared to the nasal cannula with a flow rate of 3 L/minute.

Brainard et al., in a randomized trial with high vs low flow O2 through a standard nasal cannula, studied whether the patient is able to tolerate the O2 via nasal cannula at high (15 L/minute) and low flow (6 L/minute) for 10 minutes.16

Their study showed that 100% of healthy participants could tolerate 10 minutes of nasal cannula O2 at 15 L/minute with some discomfort and without major adverse events. In our study, too, all participants could tolerate the nasal cannula oxygenation at 10 L/minute; however, 64.4% of the participants expressed discomfort on direct questioning.

Our study had a few limitations such as, we did not measure the EtO2 with 0 L/minute flow rate, which would have estimated the leak caused by the addition of a nasal cannula, healthy volunteers were enrolled for the study and hence, the findings might not be applicable to patients with comorbidities.

CONCLUSION
Preoxygenation with the conventional method at 12 L/minute and the conventional method supplemented with the nasal cannula at 3 L/minute, and 10 L/minute is efficacious. The use of a nasal cannula at a flow rate of 3 L/minute, along with conventional preoxygenation, can cause a reduction in EtO2 as compared to conventional method alone. Preoxygenation is enhanced by nasal cannula at 10 L/minute, but the same should be titrated against the comfort of the patient. Nasal prongs, an easily available, simple, noninvasive, and inexpensive device could be routinely incorporated with airway management at a flow rate of 10 L/minute to enhance preoxygenation.

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