Oronasal Masks Require a Higher Pressure than Nasal and Nasal Pillow Masks for the Treatment of Obstructive Sleep Apnea

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Study Objectives: Oronasal masks are frequently used for continuous positive airway pressure (CPAP) treatment in patients with obstructive sleep apnea (OSA). The aim of this study was to (1) determine if CPAP requirements are higher for oronasal masks compared to nasal mask interfaces and (2) assess whether polysomnography and patient characteristics differed among mask preference groups.

Methods: Retrospective analysis of all CPAP implementation polysomnograms between July 2013 and June 2014. Prescribed CPAP level, polysomnography results and patient data were compared according to mask type (n = 358).

Results: Oronasal masks were used in 46%, nasal masks in 35% and nasal pillow masks in 19%. There was no difference according to mask type for baseline apnea-hypopnea index (AHI), body mass index (BMI), waist or neck circumference. CPAP level was higher for oronasal masks, 12 (10–15.5) cm H2O compared to nasal pillow masks, 11 (8–12.5) cm H2O and nasal masks, 10 (8–12) cm H2O, p < 0.0001 (Median [interquartile range]). Oronasal mask type, AHI, age, and BMI were independent predictors of a higher CPAP pressure (p < 0.0005, adjusted R² = 0.26.). For patients with CPAP ≥ 15 cm H2O, there was an odds ratio of 4.5 (95% CI 2.5–8.0) for having an oronasal compared to a nasal or nasal pillow mask. Residual median AHI was higher for oronasal masks (11.3 events/h) than for nasal masks (6.4 events/h) and nasal pillows (6.7 events/h), p < 0.001.

Conclusions: Compared to nasal mask types, oronasal masks are associated with higher CPAP pressures (particularly pressures ≥ 15 cm H2O) and a higher residual AHI. Further evaluation with a randomized control trial is required to definitively establish the effect of mask type on pressure requirements.

Keywords: obstructive sleep apnea, CPAP, treatment, mask, nasal pillows, nasal mask, oronasal mask

Commentary: A commentary on this article appears in this issue on page 1208.


INTRODUCTION

Obstructive sleep apnea (OSA) is characterized by excessive daytime sleepiness due to recurrent episodes of partial (hypopnea) or complete (apnea) obstruction of the upper airway during sleep. OSA is highly prevalent and moderate-severe OSA is reported to affect 17% of men and 9% of women older than 50 years. Untreated OSA is associated with significant morbidity and mortality, with increased risk of hypertension, depression, motor vehicle accidents, cardiovascular disease, and premature death. The mainstay of therapy for OSA is nocturnal continuous positive airway pressure (CPAP), which prevents collapse by pneumatically splinting the upper airway. CPAP has been shown to reduce daytime somnolence, improve quality of life, and improve nocturnal oxygen saturation.

CPAP has also been shown to reduce blood pressure, and in severe OSA, compliant CPAP usage has been associated with reduced risk of cardiovascular disease and mortality.

Various interfaces are available for the delivery of effective CPAP and most can be divided into 3 categories—nasal masks which cover the nose and leave the mouth free; nasal pillows which insert directly into the nostrils; and oronasal (i.e., full face) masks, which cover the nose and the mouth. The CPAP level required to treat OSA varies between individuals. It has been reported that selected patients require higher CPAP levels with oronasal masks compared to nasal masks; however, the literature on whether CPAP requirements differ according to mask type is conflicting. A Cochrane review in 2006 concluded that due to an inadequate number of studies addressing the issue, the optimal CPAP interface was unclear. Since then, both Bakker et al. and
Teo et al. have shown that pressure requirements of nasal and oronasal masks are equivalent, but it is important to note that both these studies had small sample sizes and may have been underpowered to detect a difference. This point is highlighted by the fact that in the study by Teo et al., 43% of patients had nasal to oronasal mask pressures differences of 2 cm H2O or more. In contrast, Bettinzoli et al. demonstrated that the required therapeutic CPAP level was higher when administered through an oronasal mask compared to nasal interfaces. In their cohort, the only independent predictor of therapeutic CPAP level was mask type, with no independent effect noted from either OSA severity or patient body mass index (BMI).

All of these above studies had small numbers and thus doubt remains as to whether there is a true difference in therapeutic CPAP level between mask types. In our clinical experience, some patients struggling on high CPAP pressures with oronasal masks are able to significantly reduce their therapeutic CPAP pressure if switched to a nasal interface. We therefore hypothesize that oronasal masks may lead to higher CPAP requirements and are more likely to be associated with suboptimal OSA control. This study was subsequently designed to determine if CPAP requirements and OSA control systematically differ between subjects using different mask types.

### METHODS

Ethical approval was obtained from the Human Research Ethics Committee at Monash Health (Application number 14297Q). This was a retrospective study of all CPAP implementation sleep studies performed at Monash Health between July 2013 and June 2014. Monash Health is a tertiary referral center in Melbourne, Australia. Referrals for CPAP implementation were received from sleep specialists following the diagnosis of OSA at Monash Health using full type 1 polysomnography (Compumedics Grael). Respiratory events were classified according to published guidelines from the American Academy of Sleep Medicine (AASM) 2007 alternate criteria.13 Referral for CPAP was based on the clinical opinion of the treating sleep specialist following the diagnosis of OSA (apnea-hypopnea index [AHI] > 5 events/h). CPAP naïve patients with OSA underwent a laboratory CPAP implementation study where education and mask fitting were performed in the evening by attending scientific staff, and CPAP pressures were manually titrated over the night according to AASM guidelines.14 Given there are no clear guidelines on mask selection currently available, our service follows its own internal procedure; therefore, mask type was chosen as follows. Prior to commencing the study, mask type was chosen by the sleep technologist following discussion with the patient. According to our protocol, a nasal or nasal pillow mask is tried first, but an oronasal mask is used if the patient has great difficulty breathing through his/her nose and is unable to keep their mouth closed.” No objective measurement of nasal patency or resistance is made.

The initial database search yielded a total of 845 sleep studies performed during the study period. One hundred sixteen split diagnostic-CPAP, bilevel PAP, and autotitrating PAP review studies, and 270 CPAP review studies were excluded in order to standardize our results. A further 101 studies were excluded as information required for analysis was not available—83 because the diagnostic polysomnography was not performed in our laboratory and 18 because the final treatment pressure was not recorded. A total of 358 CPAP implementation studies were therefore included in the analysis. A flow diagram highlighting recruitment is included in Figure 1.

### Statistical Analysis

Comparative statistics were performed on Prism (version 6.0, 2014, California, USA). Multilinear Regression Analysis was performed on SPSS (version 22, 2013, New York, USA) and included demographics, OSA severity, and AHI to establish the predictors of prescribed CPAP level. Analysis of variance
RESULTS

Table 1 shows the baseline demographic data of patients divided between different masks types. Nasal pillow masks were used by 19.3% of patients, nasal masks by 34.6%, and oronasal masks by 46.1%. Use of chinstraps was minimal in our cohort, with only 6 patients having a chinstrap added during their sleep study—2 in the nasal pillow group, 3 in the nasal mask group, and 1 in the oronasal mask group. There was no statistically significant difference in baseline characteristics between the 3 groups including age, sex, neck circumference, Epworth Sleepiness Scale (ESS), or baseline AHI. However, there was a nonsignificant trend for BMI to be elevated in the oronasal group compared to the nasal groups (p = 0.08). Median CPAP level was higher in the oronasal group compared with the nasal pillow and nasal mask groups (12 cm H\textsubscript{2}O v 11 cm H\textsubscript{2}O v 10 cm H\textsubscript{2}O, respectively), p < 0.0001. Furthermore, residual AHI during polysomnography was significantly higher in the oronasal group compared to nasal and nasal pillow interfaces (p < 0.001).

To determine the predictors of CPAP level, a multilinear regression analysis was performed which included age, gender, AHI, BMI, and mask type as independent variables. The assumptions of linearity, independence of errors, homoscedasticity, usual points, and normality of residuals were met. Apart from gender, all independent variables significantly predicted prescribed CPAP level ($F_{5,352} = 26.14$, $p < 0.0005$; adjusted $R^2 = 0.26$). Mask type had the largest regression coefficient (1.05, SE 0.23; Table 2).

Analysis of the subgroup of patients who required a CPAP level ≥ 15 cm H\textsubscript{2}O (n = 70) revealed that the majority of these patients used an oronasal mask during their CPAP study (Figure 2). For patients receiving ≥ 15 cm H\textsubscript{2}O, there was an unadjusted odds ratio of 4.5 (95% CI 2.5–8.0) for having an oronasal mask compared to a nasal or nasal pillow mask.

### Table 1—Demographics of patients.

<table>
<thead>
<tr>
<th></th>
<th>Nasal Pillows (n = 69)</th>
<th>Nasal Mask (n = 124)</th>
<th>Oronasal Mask (n = 165)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mask type (%)</td>
<td>19.3</td>
<td>34.6</td>
<td>46.1</td>
<td></td>
</tr>
<tr>
<td>Male (%)</td>
<td>56.5</td>
<td>62.1</td>
<td>66.7</td>
<td></td>
</tr>
<tr>
<td>Age (± 15)</td>
<td>57</td>
<td>56 (± 14)</td>
<td>59 (± 14)</td>
<td>0.27</td>
</tr>
<tr>
<td>BMI (28.5, 41.3)</td>
<td>33.3</td>
<td>32.8</td>
<td>35.1</td>
<td>0.08</td>
</tr>
<tr>
<td>Neck circumference (± 4.6)</td>
<td>40.93 (± 4.6)</td>
<td>40.8 (± 5.0)</td>
<td>41.35 (± 4.3)</td>
<td>0.60</td>
</tr>
<tr>
<td>ESS (5, 9.5)</td>
<td>8</td>
<td>7 (5, 11)</td>
<td>8 (5, 12)</td>
<td>0.74</td>
</tr>
<tr>
<td>Baseline AHI</td>
<td>38.6 (23.9, 77.5)</td>
<td>40.2 (21.2, 63.1)</td>
<td>43.1 (24.2, 66.2)</td>
<td>0.59</td>
</tr>
<tr>
<td>Residual AHI</td>
<td>6.7 (2.8, 14.3)</td>
<td>6.4 (2.8, 11.9)</td>
<td>11.3 (4.5, 20.3)</td>
<td>0.0005</td>
</tr>
<tr>
<td>CPAP level (8, 12.5)</td>
<td>11 (8, 12.5)</td>
<td>10 (8, 12)</td>
<td>12 (10, 15.5)</td>
<td>&lt; 0.0001</td>
</tr>
</tbody>
</table>

Data are presented as: mean (± SD) for normally distributed data; or median (interquartile range; IQR) for nonparametric data. BMI, body mass index; ESS, Epworth Sleepiness Scale; AHI, apnea-hypopnea index; CPAP, continuous positive airway pressure.

### Table 2—Variables predictive of prescribed CPAP level.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unstandardized β Co-efficient</th>
<th>95% CI for β</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.03</td>
<td>0.006 to 0.053</td>
<td>0.02</td>
</tr>
<tr>
<td>Gender</td>
<td>−0.75</td>
<td>−1.46 to −0.46</td>
<td>0.04</td>
</tr>
<tr>
<td>AHI</td>
<td>0.05</td>
<td>0.04 to 0.06</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>BMI</td>
<td>0.03</td>
<td>0.01 to 0.06</td>
<td>0.002</td>
</tr>
<tr>
<td>Mask type</td>
<td>1.05</td>
<td>0.60 to 1.49</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

(ANOVA) was performed on parametric data, while the equivalent Kruskal-Wallis test was performed for nonparametric data.

Figure 2—Frequency plot of CPAP mask usage.

NP, nasal pillow mask; nasal, nasal mask; O, oronasal mask. Black bars are frequency of mask use in whole study population. Grey bars are frequency of mask use in patients requiring CPAP ≥ 15 cm H\textsubscript{2}O. For patients using CPAP ≥ 15 cm H\textsubscript{2}O, after adjusting for baseline AHI and BMI there was an odds ratio of 4.8 (95% CI 2.6–9.1) for having an oronasal mask compared to a nasal or nasal pillow mask.
DISCUSSION

Our study demonstrates that oronasal masks were associated with higher CPAP requirements and led to a higher residual AHI when compared to nasal and nasal pillow interfaces. Moreover, our study is the first to demonstrate that patients using oronasal masks are substantially more likely to require high CPAP ≥ 15 cm H₂O. We demonstrated using multilinear regression that although there was a small influence of age, AHI, and obesity (as determined by BMI) on the therapeutic CPAP pressure, the major independent determinant of CPAP pressure was oronasal mask type.

CPAP is the mainstay of treatment for OSA. Given that CPAP is almost universally effective at controlling OSA, adherence to treatment is the major impediment to long-term effectiveness.15–17 Moreover, it is well established that early CPAP compliance and support is the best predictor of long-term CPAP usage.18 The comfort and type of mask interface are believed to be crucial to the tolerability of CPAP therapy, as CPAP-related side effects are associated with CPAP non-adherence.19 Side effects from CPAP include pressure intolerance, skin irritation, mask leak with secondary sleep disturbance, claustrophobia, and aerophagia. Although it is suggested that the use of an oronasal CPAP mask affects tolerance of and adherence to treatment,19 somewhat surprisingly, there are no established guidelines to aid technicians, scientists, and clinicians when choosing an initial CPAP mask interface. In our laboratory, sleep scientists and technicians generally choose a nasal or nasal pillow interface unless there is significant nasal obstruction or evidence of mouth leak; however, decisions about when to switch to an oronasal mask are left to the individual practitioner in discussion with the patient.

Previous literature has led to conflicting results about whether CPAP pressure requirements differ according to mask type. Bakker et al. did not find any difference in CPAP pressure between oronasal and nasal masks, although they did find a small but significantly higher residual AHI and increased leak with oronasal masks.19 However, this randomized controlled crossover trial had very small numbers, with only 12 subjects completing the trial; hence the study was potentially underpowered to detect any difference between mask types. Furthermore, they recruited patients who were currently using CPAP with a nasal mask, which may limit the generalizability of the results to CPAP naïve patients. Beecroft et al. also did not show a difference in CPAP pressure between oronasal and nasal masks.20 However, the number of subjects using an oronasal mask were too small to draw definitive conclusions (only 7% of the 98 patients in the study used an oronasal mask) and there was a nonsignificant trend towards a 2 cm H₂O higher pressure in the oronasal group. Similarly, Teo et al. studied 24 CPAP naïve subjects and performed a randomized crossover study over two consecutive nights using a nasal and oronasal mask in random order.11 There was no difference in autotitrating CPAP-determined pressure between mask types, but residual AHI and mask leak were higher with an oronasal mask, total sleep time with the oronasal mask was lower, and the majority of subjects preferred the nasal mask. Furthermore, in this study 43% of patients had nasal to oronasal mask pressure differences of 2 cm H₂O or more, raising the possibility of a type II error and the study being underpowered to detect a true difference in pressure requirements between mask types.

In contrast, a number of studies have shown that similar to our study, oronasal masks lead to higher CPAP pressures. Ebben et al. studied 55 subjects and showed a significantly higher pressure requirement for oronasal compared to nasal and nasal pillow masks.21 For moderate OSA, the difference was 2.8 cm H₂O, and for severe OSA the difference was 6.0 cm H₂O. Residual AHI was the same between the two mask types. Bettin zoli et al. performed a retrospective study on 109 subjects with moderate-severe OSA.22 They demonstrated a 1.2 cm H₂O higher CPAP pressure with oronasal masks, as well as a higher residual AHI. Finally, Borel et al. looked specifically at predictors of long-term CPAP usage. Although their study was not designed to look at CPAP pressure differences between mask types, CPAP non-adherence was associated with the use of oronasal masks (odds ratio 2.0; 95% CI 1.6–2.5) along with other factors such as depression and CPAP related side effects. Taken together, these previous studies suggest that oronasal masks may lead to higher CPAP pressures and poorer OSA control in some patients. Our data confirm this, with the advantage of looking at larger numbers of subjects using all 3 major mask types. In particular, our results showing that high CPAP level (≥ 15 cm H₂O) is very strongly associated with oronasal mask use suggest that a small subgroup of OSA patients have very high CPAP requirements when using oronasal masks.

An interesting finding of our study is that there was a higher residual AHI in those patients who used an oronasal mask compared to nasal or nasal pillow masks. There are two possibilities for this finding. Firstly, it may be harder to control upper airway obstruction despite higher pressures with an oronasal mask—therefore there is more unresolved OSA. In support of this is the fact that multiple other studies have demonstrated similar findings.10–12 In addition, a recent study by Eb ben et al. has demonstrated that nasal masks were more effective at opening the upper airway in the retropalatal region than oronasal masks at a range of CPAP pressures.23 The authors hypothesized that this may explain the higher residual AHI with oronasal masks seen in some studies. Alternatively, the higher AHI could be an artifact of the need for a higher CPAP pressure. Our study was performed with a single-night CPAP titration polysomnogram. CPAP was therefore manually titrated upwards throughout the night in response to OSA at lower pressures. The fact that patients using an oronasal mask required higher pressures means that more time is inherently spent at subtherapeutic CPAP levels. We believe the higher residual AHI with oronasal masks in our study is likely to be a result of both these mechanisms; however, the
only way of definitively determining whether oronasal masks truly lead to poorer OSA control is to perform a randomized controlled trial of longer term CPAP use, rather than just a single night.

The mechanisms underlying the higher CPAP pressure requirements with oronasal masks have not been systematically studied; however, we speculate that there are two possible explanations. Firstly, oronasal masks may lead to posterior displacement of the mandible in selected patients. In support of this, in a small study of six subjects, Kaminska et al. showed that adding a mandibular advancement splint to CPAP with an oronasal mask enabled the CPAP requirement to be significantly lowered in three of the subjects. Furthermore, mouth opening is an inherent feature of oronasal mask use, and mouth opening has previously been demonstrated to increase upper airway collapsibility. Another possible explanation is that breathing through the mouth with an oronasal mask leads to the soft palate being pushed posteriorly, which may counteract the opening forces of nasal airflow and lead to a narrower airway than seen when using a nasal mask. In support of this hypothesis is a recent study using magnetic resonance imaging, which showed that nasal masks were more effective at opening the upper airway in the retropalatal region (but not retroglossal) compared to oronasal masks. Given that the exact mechanism is uncertain, it would be useful to perform a study assessing the anatomical effects of different mask types, as well as measuring the physiological traits contributing to OSA (including the anatomical predisposition to airway collapse) with both a nasal and oronasal mask to determine which physiological traits are affected most by mask type.

Our study has a number of limitations that need to be considered. Most importantly, this is a retrospective study, and even though we had large numbers of patients using each mask type, patients were not randomized to the different mask types. It is possible that there is an inherent bias with subjects needing a higher CPAP requirement also exhibiting factors that require the use of an oronasal mask. Nevertheless, there was no significant difference between baseline OSA severity, age, or BMI among the three different mask groups, suggesting that these factors are not the major determinants of CPAP requirements. Our regression analysis also supports this as the major independent determinant of CPAP was mask type. However, note that we do not have data on mouth breathing or degree of nasal obstruction; therefore, this could not be included in the regression model and we cannot comment on the role of these factors on a patient’s pressure requirements. Our study was also from a single center, and it would be important to replicate these findings in other sleep services to strengthen our conclusions. Despite this, our results do mirror those of Bettinzoli et al.

In summary, oronasal masks are associated with higher CPAP requirements and higher residual AHI compared to nasal and nasal pillow masks. Patients using oronasal masks are also significantly more likely to require very high CPAP levels (≥15 cm H2O) than nasal type interfaces. This may affect patient comfort and subsequent adherence to CPAP treatment. Nevertheless, whether oronasal masks truly lead to higher CPAP levels or whether the sleep technologist determined choice of an oronasal mask reflects elevated nasal resistance (which itself is the cause of higher CPAP requirements) cannot be determined from our study. Our findings therefore support the need for an adequately powered randomized controlled trial to definitively address this issue.

**ABBREVIATIONS**

AASM, American Academy of Sleep Medicine
AHI, apnea-hypopnea index
ANOVA, analysis of variance
BMI, body mass index
CPAP, continuous positive airway pressure
ESS, Epworth Sleepiness Scale
IQR, inter quartile range
OSA, obstructive sleep apnea

**REFERENCES**


