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ORIGINAL RESEARCH

Effects of continuous positive airway pressure in patients at high risk of obstructive sleep apnea during propofol sedation after spinal anesthesia

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Abstract

In patients with obstructive sleep apnea, short-term use of a continuous positive airway pressure mask improves oxygenation, decreases the apnea-hypopnea index, and reduces hemodynamic instability. In this study, we investigated the effects of use of a continuous positive airway pressure mask in patients at high risk of obstructive sleep apnea during propofol sedation after spinal anesthesia. Forty patients who underwent propofol sedation after spinal anesthesia for transurethral bladder or prostate resection with a STOP-Bang score of 3 or more were enrolled in this study. Patients were randomly divided into two groups: a simple oxygen mask group (n = 20) and a continuous positive airway pressure mask group (n = 20). After spinal anesthesia, propofol was injected at a target concentration of 1.3 mcg/ml via a target concentration control injector. ApneaLink™ was applied to all patients. Patients in the simple oxygen mask group were administered oxygen at a rate of 6 L/min through a simple facial mask. Patients in the CPAP mask group were connected to a pressurizer, and oxygen (6 L/min, 5–15 cm H_2O) was administered. Blood pressure, heart rate, respiratory rate, and oxygen saturation were recorded preoperatively, after spinal anesthesia, and every 5 min after the injection of propofol to observe hemodynamic changes. Apnea-hypopnea index was estimated using ApneaLink™. There were no significant differences in hemodynamic changes between the two groups. Apnea-hypopnea index was significantly reduced in the continuous positive airway pressure mask group compared to the simple facial mask group. Application of a continuous positive airway pressure mask in a patient at high risk of obstructive sleep apnea can lower the incidence of obstructive sleep apnea during sedation without a significant effect on hemodynamic stability.

Keywords Apnea-hypopnea index · Continuous positive airway pressure · Obstructive sleep apnea · Propofol · STOP-Bang score

1 Introduction

The prevalence of obstructive sleep apnea (OSA) in the total population is approximately 3–7% for adult men and 2–5% for adult women in the general population [1], and approximately 82–92% of patients with moderate to severe obstructive sleep apnea are undiagnosed [2]. In the presence of obstructive sleep apnea, hypoxia, reduced oxygen saturation, decreased pressure receptor reflexes, and sympathetic hyperactivity can also occur, which might increase the incidence of cardiovascular disease [3–5]. OSA is also known as a risk factor for heart failure and pulmonary hypertension [6].

Hypoxic events and airway obstruction can lead to cardiovascular disturbance or collapse and need for advanced airway management (i.e., face mask, supraglottic airway,

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and tracheal tube intubation). Drugs for anesthesia or sedation can increase the severity of obstructive sleep apnea, and tracheal intubation can be challenging in patients with OSA [3, 7, 8].

To diagnose OSA, a polysomnography test is required. A polysomnography test is a method of diagnosing the sleep of the patient by analyzing electroencephalograms, electrooculograms, electromyograms, and electrocardiograms. However, this method requires a large amount of time to screen patients (up to 12 h per patient) and is expensive. Therefore, the STOP-Bang questionnaire is used to identify patients at high risk of sleep apnea before surgery. The STOP-Bang questionnaire consists of eight questions. If a patient answers “yes” to a question, they are assigned 1 point. If they answer “no,” they receive 0 points. These scores are summed to calculate a score from 0 to 8 points. A score of 3 or more is considered highly suggestive of the presence of OSA [9]. A previous study reported that a STOP-Bang score of 3 or more had a sensitivity of 93–100% for diagnosing patients with moderate to severe OSA [9]. As the STOP-Bang score increases, the probability of having OSA increases [10, 11].

Depending on the type and region of the operation, local anesthesia or regional anesthesia can be performed instead of general anesthesia. To increase the comfort and satisfaction of patients during local or regional anesthesia, patients can be sedated during surgery with medications such as propofol while maintaining spontaneous breathing.

Propofol is known to increase the collapsibility of the upper airway by reducing the activity of the genioglossus muscle in proportion to its concentration [12]. This can aggravate OSA in patients sedated with propofol. In a previous study, high-risk patients with OSA had a significantly higher apnea-hypopnea index than low-risk patients when sedated with propofol after spinal anesthesia [13].

Currently, continuous positive airway pressure (CPAP) is recommended for the treatment of patients with OSA [14, 15]. Recent studies have demonstrated that, in patients with OSA, short-term use of a CPAP mask can improve oxygenation, decrease the apnea-hypopnea index, and reduce the variability of cardiovascular parameters such as blood pressure and heart rate [5, 16].

A CPAP mask offers noninvasive ventilation, and can deliver CPAP or bi-level positive airway pressure. Continuous positive airway pressure is constant, while bi-level positive pressure consists of an inhalation pressure and an exhalation pressure. A CPAP machine has a small pump that delivers air through the mouth and nose via the connected pipe and mask. When constant pressure is delivered through this machine, the pressure on the alveolar surface rises, and oxygenation is maintained. Application of pressure keeps the alveoli constantly open, reducing breathing effort during inspiration. There are two types of CPAP masks; a mask covering the nose and a frontal mask covering both the nose and mouth.

Apnea-hypopnea index is a measure of the severity of a patient’s sleep apnea. Apnea-hypopnea index is a measure of the number of apneas and hypopneas per hour. Apnea refers to airflow stoppage for more than 10 s, and hypopnea means that the airflow is reduced by more than 50% [13]. Apnea-hypopnea is defined as mild when the low breathing index is more than 5 and less than 15, moderate if more than 15 and less than 30, and severe if it is not less than 30 [17].

The primary goal of this study is to compare changes in the apnea-hypopnea index and cardiovascular vital signs between two groups of patients at high risk for OSA who underwent propofol sedation after spinal anesthesia: those who received oxygen via a simple oxygen mask group during surgery and those who received oxygen via a CPAP mask during surgery. The secondary goal of this study is to compare the amount of anesthetic drug required depend on the masks used.

2 Methods

This study was conducted at a university hospital and was approved by the Committee for Clinical Ethics (IRB No. 2012-09-011-009). Informed consent was obtained from all individual participants included in the study.

Patients who underwent transurethral bladder or prostate resection under spinal anesthesia with propofol sedation between March 2014 and June 2016 were included. Forty patients with a STOP-Bang (Snoring, Tiredness, Observed stopped breathing, BP, BMI, Age, Neck circumference, Gender) score of 3 points or more based on the STOP-Bang questionnaire were included in this study.

Patients who were previously diagnosed and treated for OSA or sleep disturbances, with saturation of percutaneous oxygen below 95%, with an ASA physical status classification of 3 or more, taking medications that could affect sleep patterns, with liver failure or kidney failure, with cardiopulmonary disease, with chest radiograph abnormalities, with a history of pneumothorax, with vesicular lung disease, or with other contraindications for spinal anesthesia (coagulation disorder, infection at the site of spinal anesthesia, etc.) were excluded from the study. Patients were randomly divided into two groups: a simple oxygen mask group (n = 20) and a CPAP mask group (n = 20).

In addition to basic patient monitoring (electrocardiogram, blood pressure, oxygen saturation), a bispectral index (BIS) sensor was attached to the patient’s forehead to assess the level of consciousness. The heart rate, the oxygen saturation were measured continuously, and the blood pressure was measured every 5 min. After recording, 1–3 mg of midazolam was given to the patients to stabilize the patients’ mood before anesthesia. Spinal anesthesia was performed at lumbar spine 4/5 or lumbar spine 3/4 after the patient was placed in a lateral position. Ten to 14 mg of 0.5% bupivacaine was injected into the spinal canal, and the patient was placed in a supine position.

After confirming spinal anesthesia to the appropriate level (between T4 and T10), propofol was infused to a target concentration of 1.3 mcg/ml using a target controlled infusion pump (Orchestra®, Fresenius vial, France), and the propofol concentration was adjusted to a bispectral index of 60–80 (light sedation). When the bispectral index was 80 or more, the target concentration of propofol was increased by 0.1 mcg/ml. When the bispectral index fell below 60, propofol injection was stopped, and the infusion was continued after an increase in the bispectral index to 60 or more.

The nasal cannula of the ApneaLink™ (Apnea-hypopnea index monitoring device, ResMed Corporation, Poway, CA, USA) was placed in the patient's nose to measure the patient's apnea-hypopnea index, and the device was placed and fixed on the chest of the patient. Then, recording was started by pressing the button on the ApneaLink™ device. Patients in the simple oxygen mask group were administered oxygen at a dose of 6 L/min through a mask, and patients in the CPAP mask group were administered oxygen (6 L/min, 5–15 cm H_2O) through a CPAP mask (ResMed Quattro Fx full face mask, San Diego, CA, USA) connected to a CPAP machine (ResMed S9 Autoset, Bella Vista, New South Wales, Australia). In this study, we used a frontal mask because the nasal cannula of the ApneaLink ™ was inserted into the nose to measure the apnea-hypopnea index. The positive pressure was set to provide the minimum continuous positive pressure to address snoring or an airflow restriction by the algorithm stored in the CPAP machine. After turning on the CPAP machine, we set the desired pressure range and pressed the start button to allow positive pressure respiration. The mask was firmly attached to the face using a strap so that there was no leakage.

Blood pressure, heart rate, respiration rate, and oxygen saturation were recorded preoperatively, after spinal anesthesia, and every 5 min after infusion of propofol to observe hemodynamic changes. Apnea-hypopnea index was analyzed using the ApneaLink™.

When oxygen saturation fell to less than 95% due to apnea during surgery, infusion of propofol was discontinued, and head tilting was performed to promote spontaneous respiration. If self-respiration did not return, mask ventilation was applied until spontaneous breathing returned.

When the oxygen saturation dropped to less than 85% during the operation, the mask was removed, and a respiratory assist (mask ventilation) was performed. Supraglottic airway and endotracheal tube intubation were prepared for the patients' safety. Patients were not included in the analysis if the spinal anesthesia level was more than T4.

In previous studies, the mean apnea-hypopnea index was estimated to be 20 and the standard deviation to be 16 after spinal anesthesia when high-risk patients (STOP-Bang score > 3) with OSA were sedated with propofol [13]. To assess if use of a CPAP mask could decrease the mean apnea-hypopnea index at a significance level of 5% and power of 80% (bilateral test), we calculated that the size of each group needed to be more than 18; therefore, we enrolled 20 patients per group to account for possible patient withdrawal.

The significance of differences in variables between the two groups was assessed used a Chi square test or Fischer's exact test depending on the expected frequency for the nominal variable. For continuous variables, a two-sample t-test or a Mann–Whitney U test was used depending on whether or not the variable followed a normal distribution. The Shapiro–Wilk test was used to test the normality of the variables. A p-value less than 0.05 was considered to indicate a statistically significant result.

3 Results

Of the 40 patients, 20 were assigned to the CPAP mask group and 18 to the simple mask group; this latter group had two fewer patients than the CPAP mask group because one patient had spinal anesthesia more than T4 and the other patient's operation time was too short for analysis. The average positive pressure applied to patients via the CPAP mask was 11.4 cm H_2O. The characteristics of the patients in each group are summarized in Table 1. There were no significant differences in STOP-Bang score, number of underlying diseases, or ASA class between the two groups.

Table 2 lists the characteristics of anesthesia and surgery. The level of spinal anesthesia and total operation times were compared; there were no significant differences in these

Table 1 Characteristics of patients

	Simple mask (N = 18)	CPAP mask (N = 20)	p value
Age (years)	65.4 ± 6.8	61.8 ± 6.2	0.093
Height (cm)	165.1 ± 4.5	167.9 ± 6.2	0.117
Weight (kg)	70.4 ± 7.1	69.9 ± 9.8	0.877
Body mass index (kg/m^2)	25.8 ± 1.8	24.8 ± 3.3	0.272
Neck circumference (cm)	40.7 ± 2.1	40.0 ± 2.7	0.388
STOP-Bang score	4.28 ± 1.1	4.25 ± 1.2	0.940
Average number of underlying diseases	0.89 ± 0.8	1.2 ± 1.1	0.309
ASA class (I/II), n	6/12	6/14	0.831

All values are mean ± standard deviation

CPAP continuous positive airway pressure, *ASA* American society of anesthesiology

Table 2 Characteristics of anesthesia and surgery

	Simple mask (N = 18)	CPAP mask (N = 20)	p value
Level of spinal anesthesia (thoracic)	8.9 ± 1.9	8.8 ± 2.0	0.890
Total operation time (min)	20.1 ± 15.8	26.7 ± 19.0	0.256
Amount of propofol (mcg/kg/min)	39.6 ± 11.1	34.9 ± 10.6	0.212
Amount of midazolam (mg)	2.03 ± 0.44	2.05 ± 0.90	0.922
Bispectral index	70.3 ± 5.5	67.7 ± 5.7	0.165

All values are mean ± standard deviation

Table 3 Hemodynamic changes of patients

	Simple mask (N = 18)	CPAP mask (N = 20)	p value
Blood pressure (mmHg)			
Before operation			
Systolic	138.2 ± 17.3	137.5 ± 16.2	0.897
Diastolic	73.5 ± 11.3	78.5 ± 10.5	0.194
After anesthesia			
Systolic	123.4 ± 15.6	119.9 ± 13.8	0.469
Diastolic	70.4 ± 7.3	74.5 ± 8.9	0.136
After propofol infusion			
Systolic	109.6 ± 13.9	106.1 ± 10.7	0.386
Diastolic	65.1 ± 8.7	69.5 ± 8.8	0.12
Heart rate (pulse/min)			
Before operation	75.5 ± 15.5	77.7 ± 11.1	0.640
After anesthesia	70.9 ± 15.3	72.8 ± 108	0.674
After propofol infusion	62.8 ± 12.6	65.6 ± 7.2	0.391
Apnea-hypopnea index	28.7 ± 15.8 (0–69)	14.1 ± 9.8 (3–35)	0.001
Oxygen saturation (%)			
Room air	98.8 ± 1.9	98.9 ± 1.2	0.86
After propofol infusion	99.8 ± 0.4	98.8 ± 1.1	0.001

All values are mean ± standard deviation (minimum–maximum)

variables between the two groups. There was also no significant difference in midazolam and propofol usage between the two groups or the bispectral index. The mean bispectral index was 70.3 ± 5.5 in the simple mask group and 67.7 ± 5.7 in the CPAP mask group.

Changes in blood pressure, pulse rate, and oxygen saturation before the operation, after spinal anesthesia, and every 5 min after propofol infusion are described in Table 3.

Apnea-hypopnea index was 28.7 ± 15.8 in the simple mask group and 14.1 ± 9.8 in the CPAP mask group. In the simple mask group, the apnea-hypopnea index had a minimum value of 0 and a maximum value of 69. In the CPAP mask group, the apnea-hypopnea index had a minimum value of 3 and a maximum value of 35 (Table 3).

As shown in Table 3, there were no significant differences in intraoperative blood pressure, heart rate, or respiratory rate between the two groups before and after anesthesia. Apnea-hypopnea index was significantly lower in the group with a CPAP mask than in the group with a simple mask.

The number of patients requiring intervention due to less than 95% oxygen saturation was three in the simple mask group and four in the CPAP mask group. In the simple mask group, two patients needed one intervention and one needed four interventions. In the CPAP mask group, three patients needed two interventions and one needed three interventions. They needed head tilting only. No other interventions like mask ventilation, supraglottic airway placement, or endotracheal tube intubation were needed. After the intervention, oxygen saturation recovered and the study continued. The mean number of interventions was 0.33 in the simple mask group and 0.45 in the CPAP mask group. There was no significant difference in the number of interventions between the two groups.

There were no patients with less than 85% oxygen saturation.

4 Discussion

We designed this study to evaluate the effects of a CPAP mask on the apnea-hypopnea index when patients at high-risk of OSA syndrome were sedated with propofol after spinal anesthesia.

Most patients with OSA are undiagnosed but are known to have higher morbidity and mortality than those without OSA [18]. Among patients undergoing surgery, the prognosis is worse for those with OSA apnea than those without. Obstructive sleep apnea is associated with increased postoperative hypoxia, respiratory insufficiency, and increased incidence of cardiovascular complications [19], as well as increased mortality during hospitalization due to pulmonary embolism [20]. Obstructive sleep apnea leads to increased transmural left and right ventricular pressures, increased sympathetic activity like increased blood pressure and heart rate, and alveolar hypoxia and hypercapnia which may cause pulmonary arteriolar vasoconstriction leading to increased pulmonary artery pressures [6].

Patients with low oxygen saturation were excluded because this study was generally directed to patients who underwent surgery and anesthesia without further work-up. Patients with low oxygen saturation are more likely to have preoperative lung disease before the operation. There is no clear cut-off point for abnormal oxygen saturation, but saturation of percutaneous oxygen below 95% is used in most adult studies [21]. The reason we excluded the patients who are already diagnosed as having OSA is that the patients who were receiving CPAP might feel less discomfort about the CPAP machine and could affect the outcome.

After screening patients, we measured the apnea-hypopnea index to determine if the selected patients had apnea during surgery when receiving propofol. An ApneaLink™ was attached to the patient to measure the apnea-hypopnea index. ApneaLink™ is a diagnostic tool that is useful for diagnosing sleep apnea. The machine consists of a small case with a nasal cannula and is secured with a belt that can be fastened to the patient's chest. After obtaining data from a patient, the machine is connected to a computer, and dedicated software is used to obtain results. Results include the apnea index, hypopnea index, start time, end time, total measurement time, and respiration rate, among other variables. ApneaLink™ has high sensitivity and specificity compared to the polysomnogram test [22, 23]. Particularly, because of the short period of time the patients spent in the operating room in our study, we did not perform polysomnogram testing but rather analyzed sleep apnea using the ApneaLink™ machine.

Known side-effects of a CPAP mask include dry mouth, nasal congestion, facial compression by masks, and abdominal swelling [24]. In our study, however, no patients complained of these side-effects, likely due to the short-term use of this mask during surgery only. The mask can initially feel tight, which can discourage patients from using the mask [24]. Therefore, we hypothesized that we would have to administer more propofol for sedation with the CPAP mask because of discomfort with the mask. However, there was no significant difference in propofol usage between the simple mask group and the CPAP mask group. Furthermore, there was no significant difference in the depth of anesthesia based on the bispectral index. This might be because the patients were in drug-induced sleep and were therefore not bothered by the inconvenience of wearing a CPAP mask.

Several studies have reported the effectiveness of non-invasive ventilation during surgery [25]. However, most of these papers are case reports. One large-scale study examined the effect of non-invasive ventilation through the nose after sedation with midazolam [26], while another investigated application of bi-level positive pressure through the nose after epidural anesthesia and propofol administration [27, 28].The former study reported changes in oxygen saturation only [26], while the latter only examined changes in arterial blood carbon dioxide tension [27, 28]. No prior study has investigated if use of a CPAP mask during surgery improves OSA during surgery. We tried to investigate the effect of CPAP even in an iatrogenic conditions.

In this study, a significant reduction in apnea-hypopnea index was observed in the group with a CPAP mask. According to previous studies, the mean AHI was 20 and the standard deviation was 16 [13]. In our study, the mean AHI was 28.7 and the standard deviation was 15.8, which is a slightly higher AHI than that reported in the previous study. The mean apnea-hypopnea index in our study indicates moderate sleep apnea. This difference between studies is presumably due to the deeper sedation of patients (BSI of 70.3) in the present study compared to the previous study (BSI 74.4). This might differ from the BSI of the normal sleep state because patients were sedated with drugs. The number of normal patients with an apnea-hypopnea index less than 5, which indicates absence of OSA, was one in the simple mask group and four in the CPAP mask group.

The conversion rate from monitored anesthetic care to general anesthesia was known as about 6.3% (2.8–10.6%) [29]. In this study, there was no case that require endotracheal tube intubation and general anesthesia in both groups. This might due to the spinal anesthesia which reduces the pain at the surgical site and the amount of opioid required for the surgery. There could be some cases of conversion to general anesthesia if the surgery got longer, and analgesic effects terminated before the conclusion of surgery.

Consistent with a previous study, no acute changes in blood pressure or heart rate due to use of a CPAP mask were observed during surgery [16]. Short-term use of a CPAP mask, such as during surgery, does not seem to significantly affect blood pressure or heart rate. In general, when a CPAP mask is applied to an awake person, blood volume decreases and cardiac output is affected, but blood pressure and heart rate are not affected [5].

Oxygen saturation was $99.8 \pm 0.4\%$ in the simple mask group and $98.8 \pm 1.1\%$ in the CPAP mask group. Although this difference is not clinically meaningful, a reason for this difference could be the improper attachment of the CPAP mask. In fact, analysis of the log file of positive pressure showed significant leakage of airflow, even though we thought the attachment of the CPAP mask was adequate. In future studies, arterial blood oxygen tension or arterial blood carbon dioxide tension should be evaluated by arterial blood gas analysis.

Our study had the following limitations. First, operations were short, lasting 10–15 min, even though the apnea-hypopnea index is determined by counting the number of apneas and hypopneas in one hour. The number of apnea and hypopnea episodes could have been overestimated by extrapolating the number of episodes in an hour based on the number of episodes in 10–15 min. It is possible that the difference between the simple mask group and the CPAP mask group was more significant. Further research is needed to determine the difference in the apnea-hypopnea index more accurately in patients undergoing 1–2 h surgeries. In addition, it might be helpful to further evaluate the degree of sedation during surgery using the Ramsay scale, although the stimulus at the time of examination could interfere with measurement of the apnea-low breathing index, which is why we measured the bispectral index. Also, there are several studies that the bispectral index has a correlation with sedation scoring systems (Ramsay score, Richmond agitation sedation scale) [30, 31]. This study investigated risk of desaturation and hemodynamic changes with the use of CPAP mask and simple mask in a small patient group who are at risk but not diagnosed with OSA based on STOP-Bang criteria. Sedation was done with propofol for an extremely short procedure. It needs to be careful in generalizing this.

Our results suggest that application of a continuous positive airway pressure mask in a patient suspected of obstructive sleep apnea will lower the incidence of apnea-hypopnea events during sedation without a significant effect on hemodynamic stability.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Appendix

STOP-bang questionnaire

1. Snoring

Do you snore loudly (loud enough to be heard through closed doors or wakes your bed-partner at night)?

2. Tired

Do you often feel tired, fatigued, or sleepy during the daytime (such as falling asleep during driving or talking to someone)?

3. Observed

Has anyone observed you stop breathing or choking/gasping during your sleep?

4. Pressure

Do you have or are you being treated for high blood pressure?

5. BMI

Body mass index more than 35 kg/m^2?

6. Age

Age older than 50?

7. Neck circumference

Neck size large? (measured around Adam's apple).

For males, is your shirt collar 17 inches (or 43 cm) or larger?

For females, is your shirt collar 16 inches (or 41 cm) or larger?

8. Gender

Is your gender male?

High risk group for sleep apnea: STOP-Bang score ≥ 3.

Low risk group for sleep apnea: STOP-Bang score < 3.

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