Perioperative Management of Patients with Obstructive Sleep Apnea

Arnaud Romeo Mbadjeu Hondjeu, Frances Chung, Jean Wong

Abstract
Obstructive sleep apnea (OSA) is the most common form of sleep-disordered breathing with up to 60% of surgical patients with moderate-to-severe OSA unrecognized at the time of preoperative assessment. OSA is a known modifier of perioperative outcomes, with an increase in difficult airway management and postoperative morbidity with early and late serious complications that may occasionally result in death. It is critical to identify at-risk patients during the preoperative period as it allows for risk stratification and mitigation, and postoperative monitoring. In this review, we will discuss the preoperative assessment, and intraoperative and postoperative management of patients with diagnosed or suspected OSA.

Résumé
Le syndrome d’apnées obstructives du sommeil (SAOS) est la forme la plus fréquente de troubles respiratoires du sommeil avec jusqu’à 60 % des patients chirurgicaux atteints de formes modérée à sévère de SAOS sans diagnostic formel ni traitement spécifique au moment de l’évaluation préopératoire. Le SAOS altère les résultats pérïopératoires, avec une augmentation de la gestion difficile des voies respiratoires et de la morbidité postopératoire associée à des complications critiques précoces et tardives pouvant parfois entraîner la mort. il est donc essentiel d’identifier les patients à risque pendant la période préopératoire enfin d’appliquer des procédures de modération de risque, ainsi que des précautions et une surveillance adéquates. Dans cette revue, après un aperçu de la physiopathologie du SAOS, nous discuterons de l’évaluation préopératoire, de la prise en charge intraopératoire et postopératoire des patients atteints de SAOS confirmée ou suspectée.

Keywords: Obstructive sleep apnea, perioperative outcomes
Perioperative management of obstructive sleep apnea patients

Perioperative management of obstructive sleep apnea patients

blockade before cautious extubation is critical. During the postoperative period, the administration of oxygen, application of continuous positive airway pressure (CPAP) if needed, continuous monitoring, and recovery of the patient in a non-supine position can reduce negative outcomes. The SAMBA particularly emphasizes the importance of neuraxial and local anesthesia techniques for their opioid sparing effect. Upon having a reasonable suspicion of OSA, the patient in our case presentation was administered neuraxial anesthesia rather than general anesthesia. Of note, multimodal analgesia was used and standard continuous monitoring with pulse oximetry and capnometry was applied intra- and postoperatively. Adequate perioperative OSA management promotes patient recovery and reduces postoperative adverse events and healthcare costs.

Epidemiology

Due to the increasing pervasiveness of obesity in western countries and improved medical awareness, the OSA prevalence has risen in the last decades. OSA is emerging as a worldwide public health concern, with a prevalence of nearly one billion people worldwide, and almost 450 million have moderate-to-severe OSA. The majority of patients with clinical OSA are undiagnosed. The diagnosis and severity of OSA are determined by the apnea–hypopnea index (AHI) which is defined as the number of apneas and hypopneas per hour of sleep.

Depending on the definition of hypopnea and the diagnostic criteria, the prevalence of OSA fluctuates. With hypopnea defined as a decrease of 4% in blood oxygen saturation, the Wisconsin Sleep Cohort Study estimated that 17.4% of women and 33.9% of men in the US aged 30–70 years had mild OSA, (AHI 5–14.9), while 5.6% of women and 13.0% of men had moderate (AHI of 15–29.9) or severe (AHI ≥ 30 events per hour) OSA. When using a more rigid criterion (AHI ≥ 5 events per hour plus symptoms or AHI ≥ 15 events per hour), the estimated prevalence of mild OSA declines to approximately 15% in males and 5% in females. The prevalence of OSA increases with age and BMI. Race can also be a determinant of the prevalence of OSA; one such example is young African Americans (<35 years) who have a higher OSA rate compared to Caucasians, independent of body weight. Notably, the prevalence of OSA in Asia is similar to that in the United States, despite lower rates of obesity. This concept is known, and the World Health Organization (WHO) defines overweight and

Case Presentation

A 53-year-old male presented to the operating room for a day for surgery reconstruction of right anterior cruciate ligament (ACL). He had no known drug allergies and no family history of anesthesia-related complications. He had two uneventful minor procedures under local anesthesia. Besides the ACL injury, he had systemic hypertension controlled with amlodipine 5 mg BID. He had a STOP-Bang score of five, body mass index (BMI) 36 kg/m², and neck circumference of 42 cm with Mallampati II.

What are your perioperative considerations and how would you manage this patient?

Overview of OSA Management

The Society of Anesthesia and Sleep Medicine (SASM), and the American Society of Anesthesiologists (ASA) and the Society for Ambulatory Anesthesia (SAMBA) have provided general recommendations for optimal perioperative management of patients with Obstructive sleep apnea (OSA) (Figure 1). These recommendations include preoperative screening and identification of at-risk patients, adoption of measures to reduce the intraoperative risk, and postoperative monitoring to lessen perioperative risks. The optimal management of OSA begins preoperatively. Identifying those at high risk of OSA allows for early adoption of preventative intraoperative strategies (i.e., regional or neuraxial anesthesia when possible, and careful monitoring) and when necessary, general anesthesia with the use of short-acting agents, multimodal analgesia, and full reversal of neuromuscular

Key Points

- Obstructive sleep apnea (OSA) is common among surgical patients and most of them may not be recognized at the time of preoperative assessment.
- Preoperative identification of at-risk patients allows for risk stratification and eventual optimization before surgery.
- Intraoperative risk mitigation strategies should be utilized because OSA is associated with an increase in difficult airway management and postoperative morbidity.
- Postoperative management includes multimodal nonopioid analgesia and enhanced monitoring for early and late serious complications that may occasionally result in death.

Case Presentation

A 53-year-old male presented to the operating room for a day for surgery reconstruction of right anterior cruciate ligament (ACL). He had no known drug allergies and no family history of anesthesia-related complications. He had two uneventful minor procedures under local anesthesia. Besides the ACL injury, he had systemic hypertension controlled with amlodipine 5 mg BID. He had a STOP-Bang score of five, body mass index (BMI) 36 kg/m², and neck circumference of 42 cm with Mallampati II.

What are your perioperative considerations and how would you manage this patient?

Overview of OSA Management

The Society of Anesthesia and Sleep Medicine (SASM),1 and the American Society of Anesthesiologists (ASA)2 and the Society for Ambulatory Anesthesia (SAMBA),3 have provided general recommendations for optimal perioperative management of patients with Obstructive sleep apnea (OSA) (Figure 1). These recommendations include preoperative screening and identification of at-risk patients, adoption of measures to reduce the intraoperative risk, and postoperative monitoring to lessen perioperative risks. The optimal management of OSA begins preoperatively. Identifying those at high risk of OSA allows for early adoption of preventative intraoperative strategies (i.e., regional or neuraxial anesthesia when possible, and careful monitoring) and when necessary, general anesthesia with the use of short-acting agents, multimodal analgesia, and full reversal of neuromuscular

blockade before cautious extubation is critical. During the postoperative period, the administration of oxygen, application of continuous positive airway pressure (CPAP) if needed, continuous monitoring, and recovery of the patient in a non-supine position can reduce negative outcomes. The SAMBA particularly emphasizes the importance of neuraxial and local anesthesia techniques for their opioid sparing effect. Upon having a reasonable suspicion of OSA, the patient in our case presentation was administered neuraxial anesthesia rather than general anesthesia. Of note, multimodal analgesia was used and standard continuous monitoring with pulse oximetry and capnometry was applied intra- and postoperatively. Adequate perioperative OSA management promotes patient recovery and reduces postoperative adverse events and healthcare costs.

Epidemiology

Due to the increasing pervasiveness of obesity in western countries and improved medical awareness, the OSA prevalence has risen in the last decades. OSA is emerging as a worldwide public health concern, with a prevalence of nearly one billion people worldwide, and almost 450 million have moderate-to-severe OSA. The majority of patients with clinical OSA are undiagnosed. The diagnosis and severity of OSA are determined by the apnea–hypopnea index (AHI) which is defined as the number of apneas and hypopneas per hour of sleep.

Depending on the definition of hypopnea and the diagnostic criteria, the prevalence of OSA fluctuates.

With hypopnea defined as a decrease of 4% in blood oxygen saturation, the Wisconsin Sleep Cohort Study estimated that 17.4% of women and 33.9% of men in the US aged 30–70 years had mild OSA, (AHI 5–14.9), while 5.6% of women and 13.0% of men had moderate (AHI of 15–29.9) or severe (AHI ≥ 30 events per hour) OSA. When using a more rigid criterion (AHI ≥ 5 events per hour plus symptoms or AHI ≥ 15 events per hour), the estimated prevalence of mild OSA declines to approximately 15% in males and 5% in females. The prevalence of OSA increases with age and BMI. Race can also be a determinant of the prevalence of OSA; one such example is young African Americans (<35 years) who have a higher OSA rate compared to Caucasians, independent of body weight. Notably, the prevalence of OSA in Asia is similar to that in the United States, despite lower rates of obesity. This concept is known, and the World Health Organization (WHO) defines overweight and
Figure 1. Summary of recommendations on the perioperative management of OSA from the Society of Anesthesia and Sleep Medicine (1), the American Society of Anesthesiologists Task Force on Perioperative Management of Patients with OSA (2), and the Society for Ambulatory Anesthesia (3).

OSA, Obstructive Sleep Apnea; PAP, Positive Airway Pressure.
Perioperative management of obstructive sleep apnea patients

Obesity among Asians with BMI cut-offs of 23 and 25 kg/m² versus 25 and 30 kg/m² in Caucasians. OSA is underestimated in the surgical population with up to 60% of surgical patients having moderate-to-severe OSA without a formal diagnosis or specific treatment by the time of the preoperative assessment. Even higher prevalence of OSA is seen in bariatric surgical patients ranging between 77% and 88%. Various studies have shown that the presence of OSA is a modifier of perioperative outcome, with an increase in difficult airway management and postoperative risk for pulmonary and cardiovascular complications with early and late critical complications that may occasionally result in intensive care unit (ICU) admission or even death. OSA severity, less intense monitoring, absence of supplemental oxygen, and higher cumulative opioid and sedative doses are factors that can lead to severe outcomes such as brain damage and death.

Pathophysiology of OSA

OSA is characterized by repetitive partial or complete pharyngeal collapse during sleep for at least 10 s, which leads to two sets of consequences: arousal from sleep to resume airflow, and gas exchange disturbances from hypopneas (reductions in breathing) or apneas (cessations of breathing). The repeated arousals in OSA lead to neurocognitive consequences including diminished memory consolidation, daytime sleepiness, and reduced quality of life. The episodes of hypoxemia and hypercapnia lead to endothelial dysfunction, oxidative stress, low-grade inflammation, and catecholamine surges; and in turn increases risk for cardiovascular and metabolic complications, arrhythmias, stroke, and sudden cardiac death.

The contraction of upper airway dilator muscles is necessary to counterbalance the negative airway pressure generated by inspiratory muscle activity to maintain airway patency. The obstruction is prevented by a reflex-mediated increase in upper airway dilation while awake. The phasic activity of genioglossus (the most important upper airway dilator muscle) prevents posterior collapse of the tongue, assisted by the levator and tensor palatini muscles (advancing and elevating the soft palate) and the geniohyoid and stylopharyngeus muscles (opposing medial collapse of the lateral pharyngeal walls). As a result, in a healthy subject, the collapsing force generated by the respiratory pump may reach a critical level of −5 cm H₂O. Most individuals with OSA have a restricted upper airway and suffer from a less negative critical level of airway collapse.

Besides this mechanism, other factors contributing to airway obstruction include extra luminal pressures caused by external pharyngeal soft tissue accumulation, body position (with a higher risk of obstruction in the supine position, compared to lateral or sitting positions), craniofacial abnormalities, fluid redistribution during the supine position or fluid overload, and lung volume which exerts a mechanical traction on the upper airway with a sleep-induced reduction in lung volume associated with a reduction of upper airway airflow.

Obstructive apneas and hypopneas result in inherently less stable ventilatory control, intermittent hypoxemia, and hypercarbia. The hypercapnic respiratory drive and diaphragmatically generated negative intrapharyngeal pressure during airway obstruction episodes cause frequent sleep arousal. The sleep fragmentation is the primary cause of excessive sleepiness in individuals with OSA. Intermittent hypoxemia, particularly with concomitant hypercapnia, activates the sympathetic nervous system and is the major contributor of the elevation of blood pressure, decreased insulin sensitivity, inflammation, increased reactive oxygen species, and metabolic abnormalities, hence contributing to the development and progression of vascular disease. Cardiovascular events are a major perioperative complication among OSA patients which may contribute to short- and long-term outcomes.

Phenotypes in OSA

The mechanisms contributing to OSA are complex and are the result of the interaction of the underlying pathophysiologic mechanisms causing different clinical manifestations (phenotype). Depending on different underlying processes, the OSA pathophysiology can be classified as anatomic (structural restriction of the upper airway) and nonanatomic (ineffective upper airway dilator muscles, fluid retention or overnight rostral fluid shift, low and high arousal threshold, unstable ventilatory control, high and low respiratory arousal threshold).

Based on the interaction between the phenotype and the environment, four key phenotypes of OSA have been identified:

1. **Impaired upper airway anatomy:** It is the most important determinant of OSA and there is a degree of upper airway anatomical impairment in all OSA patients.
2. **Low respiratory arousal threshold:** These patients wake up easily because of minor pharyngeal narrowing.
3. **High loop gain:** These patients have an unstable control of breathing due to high sensitivity to small changes in carbon dioxide (CO₂).
4. Poor upper airway muscle responsiveness.
The majority of patients with OSA have an impairment in one or more of the nonanatomical phenotypic traits (low respiratory arousal threshold, high loop gain, and poor upper airway muscle responsiveness). Each OSA phenotype is susceptible to specific perioperative risk factors. For example, a low respiratory arousal threshold has shown to be a key contributor to OSA. A premature arousal in patients with a low respiratory arousal threshold phenotype results in inadequate build-up of respiratory stimuli, precluding recruitment of upper airway dilator muscles.

The administration of sedatives such as benzodiazepines was significantly associated with induced mild respiratory depression in chronic pain patients taking opioids, but paradoxically this reduced severity of sleep apnea in these patients by increasing the respiratory arousal threshold. If sleep can be maintained in these patients using a sedative or a hypnotic without impairing pharyngeal muscle activity, the accumulation of stimuli (CO₂ and negative pharyngeal pressure) may allow for recruitment of upper airway pharyngeal dilator muscles to enable stable breathing in many cases.

OSA is a heterogeneous disease with multiple underlying mechanisms, an understanding of these phenotypes and their interactions with perioperative risk factors is critical to providing safer personalized care for patients with OSA. At present, the characterization of OSA phenotypes is an emerging topic and remains challenging. Should this become feasible in future, the recognition of different phenotypes can potentially guide individualized clinical management and improve the perioperative risk stratification and outcomes.

Preoperative Screening for OSA

Due to the high prevalence of OSA in the surgical population, it is important to identify at-risk patients during the preoperative period as it allows time for the application of risk stratification and mitigation, appropriate postoperative disposition, and monitoring. The ASA, SASM, and SAMBA recommend that all patients with risk factors or suspicion of OSA undergo a comprehensive preoperative assessment. This assessment includes medical record review, patient and family interviews, physical exam, and screening protocols.

Several screening tools have been validated and are available for preanesthetic risk stratification of OSA patients including the STOP-Bang questionnaire, the Perioperative Sleep Apnea Prediction Score, the Berlin Questionnaire, and the ASA checklist.

The STOP-Bang questionnaire is the commonly used and validated screening tool for OSA; it consists of four dichotomous self-reportable variables, (STOP: Snoring, Tiredness, observed apnea, and high blood Pressure) and four dichotomous demographic items (Bang: BMI, age, neck circumference, gender) with one point attributed to each positive answer, leading to a score range of 0–8. It is straightforward, self-reportable, and can be completed within 1–2 min. In the surgical setting, the sensitivity of a STOP-Bang score ≥3 is 84%, 93%, and 100% to predict all OSA ([AHI ≥ 5), moderate-to-severe OSA (AHI≥15), and severe OSA (AHI≥30), respectively.

In case of a positive screening test for OSA in the absence of preoperative polysomnography (PSG), the patient should be treated as having OSA and considered at increased risk for perioperative complications. However, the surgery does not need to be delayed if the patient’s comorbid conditions are optimized and if the postoperative pain can be managed predominantly with nonopioid analgesics.

There are no specific physical examination findings to OSA, although it is approximately twice as common in individuals who are overweight and four times as common in individuals with obesity than without obesity. Examination of the upper airway may identify anatomic abnormalities, such as tonsillar hypertrophy, macroglossia, or retrognathia, but normal airway findings do not exclude OSA. If the clinical evaluation suggests OSA, diagnostic confirmation requires sleep studies.

The diagnostic test is lab PSG, during which both sleep and respiratory parameters are monitored. However, PSG requires overnight admission and is a time-consuming, labor-intensive, and costly procedure that is not readily available. Home sleep apnea testing (HSAT) with portable devices may be used in some countries to diagnose OSA as alternatives to PSG. This approach to OSA diagnosis has been shown to be accurate and cost-effective. Although practice guidelines recommend HSAT in the setting of a high probability of OSA and absence of significant cardiopulmonary problems, high diagnostic accuracy has been demonstrated in stroke patients with moderate suspicion of OSA. Currently, there is a lack of evidence to support delaying surgery to perform a PSG or HSAT. It is unclear whether establishing CPAP before surgery reduces perioperative complications. As well, the minimum duration of CPAP use to reduce postoperative complications in unknown.
Decisions Regarding Surgical Setting: Inpatient or Outpatient

Although OSA patients are at an increased perioperative risk, patient selection for inpatient versus outpatient setting remains controversial.1 Despite the significance of postoperative monitoring in patients with OSA, the current literature is insufficient to guide the appropriate timing of discharge to unmonitored settings. Szeto et al., have shown that patients with moderate, high-risk, or diagnosed OSA can safely undergo outpatient and advanced ambulatory oncology surgery without increased healthcare burden of extended stay or hospital admission and avoid adverse postoperative outcomes.3 These findings have been confirmed by a recent study by Rosero et al., which demonstrated that the complications and 30-day readmission rates after airway surgery for OSA are low with no significant differences in the composite outcome of 30-day readmissions, reoperations, or complications between inpatient and outpatient settings.4 A multidisciplinary consensus addressing the perioperative care of OSA patients undergoing upper airway surgery has been published.5 The consensus reaffirmed that the determination of whether a surgical patient with suspected or diagnosed OSA is most appropriately performed on an inpatient or outpatient basis depends on multiple factors: (1) Patient factors: OSA severity and patient adherence to therapy, optimized coexisting diseases, and age; (2) Procedure factors: type of surgery, surgical urgency, type of anesthesia, and need for postoperative opioids; (3) Structural factors: adequacy of post-discharge observation and capabilities of the outpatient facility.

Patients with suspected or diagnosed OSA with optimized comorbid medical conditions can safely undergo ambulatory surgery if the postoperative pain can be managed principally with nonopioid analgesics.3 The continuous perioperative use of positive airway pressure (PAP) devices is recommended in case of known OSA diagnosis.5 Patients should resume CPAP after discharge. Education of the patient and family regarding the use of nonopioid drugs and the minimization of opioids after discharge should be implemented. OSA patients with nonoptimized comorbid medical conditions may not be good candidates for ambulatory surgery. The aforementioned measures are recommended based on a consensus reached by the Society for Ambulatory Anesthesia.3

Preoperative Preparation

Adherent patient

Weight loss, PAP therapy, and the implementation of mandibular and oral appliances are the principal medical treatments for OSA. Patients with an OSA diagnosis and prescription of CPAP up to 5 years before surgery have significantly decreased risk for postoperative cardiovascular events, compared to patients with undiagnosed OSA.56 Both myocaridal infarctions and unplanned reintubations are higher in untreated OSA patients.17,57 In case of severe OSA, the perioperative application of CPAP decreases postoperative AHI and is associated with a reduced length of hospital stay.58 Furthermore, perioperative use of alternative treatments such as oral appliance, positional therapy pillows, or hypoglossal nerve stimulators should be continued. If questions or concerns emerge about effectiveness of therapy, a referral prior to surgery to their sleep specialist is recommended.43

PAP nonadherent patient

Due to discomfort, the compliance with PAP is generally low. It is recommended not to delay surgery in patients with diagnosed OSA but CPAP nonadherent prior to surgery.1 In patients with certain comorbid conditions such as uncontrolled systemic disease including pulmonary hypertension,59 hypoventilation,60 or resting hypoxemia,61 the risk of postoperative complications is elevated, and further referral for optimization is recommended.1

Intraoperative Management

During the intraoperative phase, adequate airway management, choice of anesthesia technique, monitoring, pain management, and class and dosage of medications are of utmost importance. The ASA,2 the SASM,1 and the American Academy of Sleep Medicine,62 have provided recommendations for the perioperative management of patients with OSA.

Airway management

OSA is often associated with obesity and multiple variations in upper airway and craniofacial anatomy abnormalities.63 A significant association between OSA and difficult ventilation and intubation has been established.64,65 Sixty-six percent of patients with unexpected difficult intubation who underwent a sleep study were diagnosed with OSA by PSG. Therefore, patients with difficult intubation are at high risk for OSA and should be screened for signs and symptoms of sleep apnea.66 Patients with OSA should be considered at risk for airway complications, and it is recommended to manage these patients according to the practice guidelines for the management of the difficult airway.67 Prudent intraoperative airway management should be implemented, including the use of regional anesthesia where possible. If general anesthesia is required, suggested precautions include ramped position
for induction and intubation, application of PAP or noninvasive positive pressure ventilation during induction, use of videolaryngoscopy and rapid sequence induction weighed against the risk of rapid oxygen desaturation following induction of general anesthesia and eventual difficult airway management. Supplemental high-flow nasal oxygen during induction may improve safe apnea time. Emergency airway devices should be readily available.

In the presence of significant predictors of difficult airway, that is, anatomical abnormalities, restriction of neck movements, it is important to consider having a fiberoptic bronchoscope available. With the widespread availability of videolaryngoscopy, it is rare to perform awake intubation; however, if this method is chosen, it should be noted that the topical anesthetics applied to the oropharyngeal and upper airway to facilitate awake tracheal intubation may further impair upper airway protective reflexes and increase the frequency of postextubation airway obstruction. Importantly, It may be preferable to use general anesthesia with endotracheal intubation versus deep sedation without a secure airway.

**Choice of anesthesia techniques**

**Sedation**

Sedative premedication should not be routinely prescribed to patients with OSA; if needed, it should be administered with caution. The same caution should be applied during procedural sedation and in postoperative recovery, given the absence of a secured airway. Sleep, sedation, and anesthesia cause a depression of upper airway function at various degrees, while there is a sustained arousal response during sleep. The arousal response is depressed during sedation and completely suppressed during anesthesia. This effect results from the depression of central respiratory output to upper airway dilator muscles and suppression of upper airway reflexes. When sedation is used, the standard of care requires respiration monitoring with capnography and pulse oximetry. Capnography results in earlier detection of respiratory depression compared to pulse oximetry and may be more appropriate for use in high-risk patients with OSA. Moreover, the use of capnography has demonstrated improved patient safety by reducing the frequency of hypoxia, severe hypoxemia, and apnea during sedation. Consider administering CPAP or using an oral appliance during sedation for patients previously treated with these modalities.

**Regional anesthesia**

A wide range of literature indicates that the implementation of regional over general anesthesia may improve postoperative outcome. OSAs postoperatively experience a worsening of sleep-disordered breathing and changes in sleep architecture, expressed as an increased AHI and exacerbation of nocturnal hypoxemia and hypercapnia.

In OSA patients undergoing lower extremity surgery, neuraxial anesthesia may decrease respiratory complications, ICU admissions, and length of stay. Similarly, upper extremity surgery can be performed under upper extremity block. Regional anesthesia avoids the need for administration of systemic anesthetics, avoids airway manipulation, and neuromuscular blockade, resulting in reduction of residual paralysis and consequent pulmonary complications. In addition to the opioid-sparing effect resulting in minor hypoxia and sleep fragmentation in OSA patients, the regional anesthesia technique provides better pain management.

**General anesthesia**

For some types of surgery, there may not be an alternative to general anesthesia. The optimal general anesthetic technique for patients with OSA should consider the use of short-acting agents that allow for a more rapid restoration of consciousness and a return to baseline respiratory function. A multimodal analgesia approach aiming for opioid-sparing effect is recommended in the perioperative setting. Neuromuscular monitoring and full reversal of neuromuscular blockade before cautious extubation is critical. After administration of reversal agents, residual effects that cause pharyngeal dysfunction, airway obstruction, and aspiration should be excluded. Airway collapse resulting from premature extubation can lead to severe negative pressure pulmonary edema. Patients with OSA should be extubated while they are awake and able to respond to commands. Importantly, OSA patients should be placed in nonsupine positions throughout the recovery process if possible. Excessive intravenous fluid administration should be minimized to avoid rostral fluid shifts that can worsen airway edema.

**Pain management**

Preoperative education, accurate pain assessment, and multimodal analgesia promote effective pain management, enhance patient recovery and rehabilitation, and may be associated with a reduction of postoperative adverse events and healthcare costs. The goal of multimodal analgesia is to improve pain relief while reducing opioid requirements and opioid-related adverse effects. Multimodal nonopioid analgesics including local anesthetic infiltration, peripheral nerve blocks and neuraxial blocks, acetaminophen,
nonsteroidal anti-inflammatory drugs (NSAIDS), and cyclooxygenase-2-specific inhibitors (COX-2) as well as analgesic adjuncts such as steroids, ketamine, and \( \alpha-2 \) agonists are currently the main modalities of pain management. Individuals with OSA are at increased risk for opioid-induced respiratory depression.\(^{83}\) Chronic recurrent nocturnal hypoxia and sleep disruption present in OSA patients may enhance the sensitivity to pain.\(^{84}\) However, the perpetual hypoxia may potentiate opioid analgesic effects resulting in alterations in pain perception with a significant reduction in postoperative opioid consumption.\(^{85}\) Intra- and postoperative parenteral opioid use have been associated with significantly higher odds for respiratory failure in patients with OSA.\(^{86}\) There is therefore a concern regarding the perioperative pain management in these high-risk patients.

Acetaminophen, a weak analgesic with rare adverse effects is an essential component of multimodal perioperative analgesia used for the treatment of mild-to-moderate pain.\(^{87}\) Its efficacy can be significantly enhanced by using appropriate doses (i.e., 1 g every 6 h, maximum 4 g/day) and by combination with NSAID or COX-2 inhibitors.\(^{88}\)

Nonselective NSAID and COX-2-specific inhibitors play an important role in prevention of peripheral and central sensitization. Despite the proven analgesic benefits, its use is limited by a few adverse effects such as bleeding, gastric irritation or ulceration, impairment of wound and bone healing, and bronchospasm in patients with reactive airway disease.\(^{89}\) To avoid the side effects of NSAIDS, the COX-2-specific inhibitors are preferred. Limiting the length of therapy to the acute phase after surgery can also reduce the eventual side effects.

Local anesthetic techniques include neuraxial anesthesia or analgesia such as epidural and paravertebral block and peripheral nerve blocks as well as wound infiltration. These approaches provide adequate pain relief and reduce opioid requirements. Thus, local anesthetic techniques should be used whenever possible in the OSA patient.

The analgesic effect of intravenous (iv) glucocorticoids is attributed to their effects on reducing the inflammatory response to surgical stress by blocking the COX and lipooxygenase enzymes. A single dose of iv dexamethasone administered perioperatively significantly reduced postoperative pain as well as opioid consumption and postoperative nausea and vomiting. It should be used when there are no contraindications. However, iv dexamethasone has been associated with mild increases in blood glucose on the first postoperative day and can be a concern in OSA patients with glucose intolerance or diabetes.\(^{90}\)

In case of regional anesthesia, perineural dexamethasone prolongs the analgesic duration of a single-shot peripheral nerve block by decreasing nociceptive C fiber activity via direct modulation of glucocorticoid receptors without any reported serious adverse effects and can be used if there is a contraindication to systemic use.\(^{91}\)

Opioids are effective for treatment of moderate-to-severe pain but is associated to some dose-related adverse effects, such as nausea, vomiting, itching, prolonged ileus, urinary retention, dizziness, drowsiness, and most importantly, respiratory depression which can be significant in OSA patients (the initial 24 h after opioid administration appear to be the most critical). Opioid use should be reserved for rescue, and the preferred route of administration should be oral.\(^{92}\)

There is a potentially greater risk for neuraxial opioid-induced respiratory depression in patients with OSA; thus, special attention should be given to signs of adverse effects after opioid administration.\(^{93}\) Preventive measures after neuraxial opioid administration include accurate decisions regarding opioid dose, type, and administration modality, such as single injection neuraxial or continuous epidural opioids versus parenteral opioids. OSA patients receiving neuraxial opioids should be continuously monitored for adequacy of ventilation, oxygenation, and level of consciousness.\(^{93}\)

Gabapentinoids inhibit central sensitization through presynaptic or postsynaptic inhibition of calcium influx, which inhibits the release of neurotransmitters from the primary afferent nerve fibers in the spinal cord. The use of gabapentinoids in multimodal analgesic regimens is associated with increased rates of perioperative respiratory depression and should therefore be avoided in patients affected with OSA.\(^{94,95}\)

Intraoperative monitoring
There is no specific type of monitoring for OSA population standard monitor recommend by ASA guidelines. With attention of capnometry and pulse oximetry during sedation, in case of general anesthesia, an attention to residual neuromuscular blockade is required. The intensity of intraoperative monitoring should be determined by the type of surgery and accompanying comorbidities in any given patient.

Postoperative Management

Patient positioning
The soft palate of the upper airway is predisposed to collapse in OSA patients. This obstruction of the upper airway is dependent on different factors including the administration of anesthetics, sedatives, opioids, and more importantly...
to the adoption of the supine position.96–98 In some phenotypes of OSA, such as those with impaired upper airway anatomy, rostral fluid shifts during the supine position may cause edema and further worsen airway obstruction.99 The lateral position can promote the maintenance of the passive upper airway aperture in OSA.100 Moreover, upper body elevation may improve upper airway stability during sleep and may minimize the abdominal compression against the diaphragm, reducing the level of PAP leading to better compliance of the patients.97,100 Whenever possible, patients should be in lateral, semi-upright, or other nonsupine positions during recovery.1,2

Oxygenation
Postoperative supplemental oxygen has been shown to improve oxygenation and decrease the AHI without increasing the duration of apnea–hypopnea events or level of transcutaneous CO₂.101 However, 11% of the patients had significant CO₂ retention that exceeded 55 mm Hg while receiving supplemental oxygen, indicating a degree of respiratory depression in the postoperative nights, mostly first postoperative night. Supplemental oxygen increases ventilatory stability in patients with ventilatory instability (high loop gain) phenotype. It has been shown to decrease AHI in patients with high loop gain but not in patients with low loop gain. When supplemental oxygen is given, it may mask the ability of oximetry to detect hypoventilation. Additional methods for detecting hypoventilation such as continuous measurement of respiratory rate or end-tidal carbon dioxide (EtCO₂) monitoring may be needed.99

Supplemental oxygen should be administered continuously to all patients who are at increased perioperative risk from OSA until they are able to maintain their baseline oxygen saturation while breathing room air.1 Supplemental oxygen therapy should be discontinued as soon as baseline oxygen saturation can be maintained with room air.101

Use of CPAP
PAP is the fundamental treatment for patients with moderate-to-severe OSA. Chronic use of PAP improves the ventilation, enhances vigilance, and cognitive function, and improves quality of life of OSA patients. The adherence to PAP therapy is reduced due to discomfort. In the perioperative setting, there is limited literature on the effectiveness of PAP in surgical patients with newly diagnosed OSA. In a study by Liao et al., the perioperative randomization of patients with newly diagnosed moderate and severe OSA who underwent auto-titrated PAP treatment resulted in significantly decreased postoperative AHI and improved oxygen saturation.102 Suen et al., found that among patients with a preoperative CPAP prescription, approximately 50% were consistently adherent pre- and postoperatively. CPAP adherence was associated with improved preoperative oxygen desaturation index, and the benefit was maintained on Night 1 after surgery.103 Due to the small sample size, two studies showed no significant difference in the postoperative adverse events between CPAP and no-CPAP treatment.58,104

The heterogeneity of OSA severity in different studies, the difficulty of randomization of PAP therapy, and the assessment of perioperative efficacy of PAP therapy remain challenging. Further research is needed in perioperative use of CPAP. Given the absence of possible adverse effects and the hypothetically beneficial effect of PAP treatment, the ASA, SASM, and SAMBA recommend the perioperative application of PAP with or without supplemental oxygen to patients already using these modalities preoperatively, particularly if OSA is severe, unless contraindicated by the surgical procedure.1–3

Postoperative monitoring
Intermittent hypoxia, hypercapnia, sympathetic activation, and associated arousals which characterize OSA have been found to increase the risk for arterial hypertension, heart failure, arrhythmias, cerebrovascular disease, metabolic diseases, and sudden cardiac death.5,23,24 Because of the residual effect of sedatives and opioids with respiratory depression, the emergence and recovery from anesthesia are of high concern. A postoperative alteration of sleep architecture with increased AHI occurred in both OSA and non-OSA patients, but OSA patients had a greater degree of postoperative change in AHI.77

A recent study has demonstrated that among at-risk patients undergoing major noncardiac surgery, unrecognized severe OSA was significantly associated with 30-day cardiovascular complications such as myocardial injury, cardiac death, congestive heart failure, thromboembolism, atrial fibrillation, and stroke. However, further research would be needed to assess whether interventions can modify this risk.17

The risk factors for postoperative respiratory depression may include the underlying severity of the sleep apnea, systemic administration of opioids, use of sedatives, site and invasiveness of surgical procedure, and sleep patterns. A combination of a preoperative OSA screening tool and identification of recurrent postanesthesia care unit (PACU)
respiratory events such as apnea, bradypnea, desaturations, and pain–sedation mismatch was associated with a higher oxygen desaturation index and postoperative respiratory complications. A two-step process consisting of identifying patients at higher risk for perioperative respiratory desaturations with preoperative screening tool and an early recognition of PACU complications have been proposed to stratify and manage surgical patients postoperatively.105

The ASA Guidelines recommend to consider monitoring in high-risk patients after discharge from PACU with severe OSA, STOP-Bang score ≥ 5, postoperative parenteral opioids, or significant comorbid conditions.2 A risk prediction model derived from continuous oximetry and capnography for 48 h has been shown to accurately predict respiratory depression episodes in patients receiving opioids on the general care ward.106

Patient monitoring is essential for the early identification of clinical deterioration of patients requiring extended care. However, the current literature is insufficient to guide the appropriate timing of discharge to unmonitored settings. This presents a significant clinical challenge, given the emergence of an increasing number of studies that have identified preventable lapses in monitoring as the predominant drivers of life-threatening adverse outcomes in OSA.78,107,108 In surgical patients after general anesthesia, monitoring with capnography and utilization of Integrated Pulmonary Index algorithm (IPI) in PACU have detected respiratory adverse events earlier than standard monitoring in 75 and 88% of cases, respectively, with an average early warning time of 8 ± 11 min. The addition of capnography and IPI to current standard monitoring may provide potential clinically relevant information on respiratory status, including early warning of some respiratory adverse events.109 Due to the growing surgical OSA population, the resources required for monitoring are an expanding concern for healthcare systems.

Studies on postoperative death and near-death events in OSA have confirmed the critical role of postoperative opioids, sedatives, and insufficient patient monitoring in this setting, with the highest risk for opioid-induced respiratory compromise happening within 24 h of opioid utilization.107 Moreover, a multiple opioid administration modality has been associated in half of the postoperative opioid-induced respiratory depression cases.108 Continuous postoperative monitoring in the first 24 h, and improved compliance with CPAP, may mitigate the risk for death or near-death events in patients with suspected or untreated OSA who require opioids after surgery.

Case Presentation Management

With a STOP-Bang score of five, this patient is at high risk for OSA. Because his hypertension is controlled, and his postoperative pain can be managed predominantly with nonopioid analgesics, we will presume he has OSA and proceed with his planned surgery on an outpatient basis with risk mitigation strategies.

In the preoperative care area, an anesthesia assistant established peripheral intravenous access. Considering the possibility of undiagnosed OSA, regional anesthesia with multimodal analgesia and sedation was planned. Acetaminophen 1000 mg was administered orally for preventive analgesia. The patient was transferred to the block room and connected to the anesthesia monitors (electrocardiogram, noninvasive blood pressure, and pulse oximeter). Midazolam 2 mg was administered, and right adductor canal block was performed for postprocedural pain management, followed by a spinal anesthetic with mepivacaine 60 mg at L2–L3. During surgery, EtCO₂ was measured in addition to the standard monitors, and the patient was sedated with a propofol infusion at 45 µg/kg/min.

After 2 h and 15 min of surgery, the patient was transferred to the PACU in a semi-upright position. He was spontaneously breathing with no obstruction with numerical rating scale pain score of 2/10. He had no nausea or vomiting and was hemodynamically stable. The postoperative course was uneventful, and patient was discharged home after 3 h of postoperative monitoring with acetaminophen 1 g q6h, celecoxib 200 mg q12h, and oxycodone 5–10 mg as needed, maximum 10 mg every 4–6 h. Patient education regarding risks of opioids and use of nonopioid analgesics was provided. At 72 h postoperation follow-up, the pain was well managed with minimal use of opioid. He was advised to follow-up with his primary healthcare provider for referral for a sleep study and sleep medicine specialist.

Screening patients for the risk of OSA allows us for to avoid airway manipulation by using local anesthetic techniques (neuraxial anesthesia and peripheral nerve blocks). Multimodal analgesia provided adequate pain management with limited opioid consumption and with no major perioperative complications.

Conclusion

OSA is a common condition in the surgical population and is characterized by increased postoperative morbidity and
mortality. Preoperative identification allows risk stratification of patients and the adoption of perioperative measures to reduce cardiopulmonary complications.

Acknowledgments

We would like to thank Ewan Scallion for the contribution in the visual sketches of the figure.

Author Contribution Statement

ARMH wrote the first draft of the manuscript. All authors contributed to critical revision of the manuscript and have agreed to the final version of the manuscript.

Competing Interests

JW received grants from the Ontario Ministry of Health and Long-Term Care, and Merck Inc. outside of the submitted work. She is supported by a Merit Research award from the University of Toronto, Department of Anesthesiology and Pain Medicine.

References

1. Memtsoudis S, Cozowicz C, Nagappa M, Wong J, Joshi GP, Wong DT, et al. Society of anesthesia and sleep medicine guideline on intraoperative management of adult patients with obstructive sleep apnea. Anesth Analg. 2018;(127):967–87. http://dx.doi.org/10.1213/ANE.0000000000003434
2. Gross JB, Apfelbaum JL, Caplan RA, Connis RT, Cote CJ, Nickinovich DG, et al. Practice guidelines for the perioperative management of patients with obstructive sleep apnea an updated report by the American society of anesthesiologists task force on perioperative management of patients with obstructive sleep apnea. Anesthesiology. 2014;120(2):268–86. http://dx.doi.org/10.1097/ALN.000000000000053
3. Joshi GP, Ankichetty SP, Gan TJ, Chung F. Society for Ambulatory Anesthesia consensus statement on preoperative selection of adult patients with obstructive sleep apnea scheduled for ambulatory surgery. Anesth Analg. 2012;115(5):1060–8. http://dx.doi.org/10.1213/ANE.0b013e318269cfd7
4. Peppard PE, Young T, Barnet JH, Palta M, Hagen EW, Ha KM. Increased prevalence of sleep-disordered breathing in adults. Am J Epidemiol. 2013;177(9):1006–14. http://dx.doi.org/10.1093/aje/kws342
5. Heinzar R, Vat S, Marques-Vidal P, Marti-Soler H, Andries D, Tobback N, et al. Prevalence of sleep-disordered breathing in the general population: The HypnoLaus study. Lancet Respir Med. 2015;3(4):310–8. http://dx.doi.org/10.1016/S2213-2600(15)00043-0
6. Benjafield AV, Ayas NT, Eastwood PR, Heinzar R, Ip MS, Morrell MJ, et al. Estimation of the global prevalence and burden of obstructive sleep apnoea: A literature-based analysis. Lancet Respir Med. 2019;7(8):687–98. http://dx.doi.org/10.1016/S2213-2600(19)30198-5
7. Redline S, Sotres-Alvarez D, Loredo J, Hall M, Patel SR, Ramos A, et al. Sleep-disordered breathing in Hispanic/Latino individuals of diverse backgrounds. The Hispanic community health study/study of Latinos. Am J Respir Crit Care Med. 2014;189(3):335–44. http://dx.doi.org/10.1164/rccm.201309-1735OC
8. Finkel KJ, Searleman AC, Tymkhew H, Tanaka CY, Saager L, Safer-Zadeh E, et al. Prevalence of undiagnosed obstructive sleep apnea among adult surgical patients in an academic medical center. Sleep Med. 2009;10(7):753–8. http://dx.doi.org/10.1016/j.sleep.2008.08.007
9. Lechner M, Breeze CE, Ohayon MM, Kotecha B. Snoring and breathing pauses during sleep: Interview survey of a United Kingdom population sample reveals a significant increase in the rates of sleep apnoea and obesity over the last 20 years-data from the UK sleep survey. Sleep Med. 2019;54:250–6. http://dx.doi.org/10.1016/j.sleep.2018.08.029
10. Redline S, Tishler PV, Hans MG, Tosteson TD, Strohl KP, Spry K. Racial differences in sleep-disordered breathing in African-Americans and Caucasians. Am J Respir Crit Care Med. 1997;155(1):186–92. http://dx.doi.org/10.1164/ajrccm.155.1.9001310
11. Lee W, Nagubadi S, Kryger MH, Mokhlesi B. Epidemiology of obstructive sleep apnea: A population-based perspective. Expert Rev Respir Med. 2008;2(3):349–64. http://dx.doi.org/10.1586/17476348.2.3.349
12. Ip MS, Lam B, Lauder IJ, Tsang KW, Chung K, Mok Y, et al. A community study of sleep-disordered breathing in middle-aged Chinese men in Hong Kong. Chest. 2001;119(1):62–9. http://dx.doi.org/10.1378/chest.119.1.62
13. Ishikawa Y, Ishikawa J, Ishikawa S, Kayaba K, Nakamura Y, Shimada K, et al. The Asia-Pacific perspective: Redefining obesity and its treatment. Melbourne, 2000.
14. Singh M, Liao P, Kobah S, Wijeysundera D, Shapiro C, Chung F. Proportion of surgical patients with undiagnosed obstructive sleep apnoea. Br J Anaesth. 2013;110(4):629–36. http://dx.doi.org/10.1093/bja/aes465
15. Frey WC, Pilcher J. Obstructive sleep-related breathing disorders in patients evaluated for bariatric surgery. Obes Surg. 2003;13(5):676–83. http://dx.doi.org/10.1080/096089203322509228
16. O’keeffe T, Patterson BJ. Evidence supporting routine polysomnography before bariatric surgery. Obes Surg. 2004;14(1):23–6. http://dx.doi.org/10.1016/j.obesurg.2003.10.002
Perioperative management of obstructive sleep apnea patients

17. Chan MT, Wang CY, Seet E, Tam S, Lai HY, Chew EF, et al. Association of unrecognized obstructive sleep apnea with postoperative cardiovascular events in patients undergoing major noncardiac surgery. JAMA. 2019;321(18):1788–98. http://dx.doi.org/10.1001/jama.2019.4783

18. Kaw R, Chung F, Pasupuleti V, Mehta J, Gay P, Hernández AV. Meta-analysis of the association between obstructive sleep apnoea and postoperative outcome. Br J Anaesth. 2012;109(6):897–906. http://dx.doi.org/10.1093/bja/aes308

19. Nagappa M, Patra J, Wong J, Subramani Y, Singh M, Ho G, et al. Association of STOP-Bang questionnaire as a screening tool for sleep apnea and peroperative complications: A systematic review and bayesian meta-analysis of prospective and retrospective cohort studies. Anesth Analg. 2017;125(4):1301–8. http://dx.doi.org/10.1213/ANE.00000000000002344

20. Opperman M, Cozowicz C, Bugada D, Mokhlesi B, Kaw R, Auckley D, et al. Does obstructive sleep apnea influence perioperative outcome? A qualitative systematic review for the Society of Anesthesia and Sleep Medicine Task Force on preoperative preparation of patients with sleep-disordered breathing. Anesth Analg. 2016;122(5):1321–34. http://dx.doi.org/10.1213/ANE.0000000000001178

21. Bolden N, Posner KL, Domino KB, Auckley D, Bennumof JL, Herway ST, et al. Postoperative critical events associated with obstructive sleep apnea: Results from the society of anesthesiia and sleep medicine obstructive sleep apnea registry. Anesth Analg. 2020;131(4):1032–41. http://dx.doi.org/10.1213/ANE.0000000000005005

22. Jenkinson C, Davies RJ, Mullins R, Stradling JR. Comparison of therapeutic and subtherapeutic nasal continuous positive airway pressure for obstructive sleep apnoea: A randomised prospective parallel trial. Lancet. 1999;353(9170):2100–5. http://dx.doi.org/10.1016/S0140-6736(98)10532-9

23. Arzt M, Young T, Finn L, Skatrud JB, Bradley TD. Association of sleep–disordered breathing and the occurrence of stroke. Am J Respir Crit Care Med. 2005;172(11):1447–51. http://dx.doi.org/10.1164/rccm.200505-702OC

24. Gami AS, Howard DE, Olson EJ, Somers VK. Anatomy of pharynx in patients with obstructive sleep apnea and in normal subjects. J Appl Physiol. 1997;82(4):1319–26. http://dx.doi.org/10.1152/jappl.1997.82.4.1319

25. Dempsey JA, Veasey SC, Morgan BJ, O’Donnell CP. Pathophysiology of sleep apnea. Physiol Rev. 2010;90(1):47–112. http://dx.doi.org/10.1152/physrev.00043.2008

26. Schwab RJ, Gupta KB, Gelfer WB, Metzger LJ, Hoffman EA, Pack AI. Upper airway and soft tissue anatomy in normal subjects and patients with sleep–disordered breathing. Significance of the lateral pharyngeal walls. Am J Respir Crit Care Med. 1995;152(5):1673–89. http://dx.doi.org/10.1164/ajrccm.152.5.7582313

27. Schwab RJ, Gupta KB, Gelfer WB, Metzger LJ, Hoffman EA, Pack AI. Upper airway and soft tissue anatomy in normal subjects and patients with sleep–disordered breathing. Significance of the lateral pharyngeal walls. Am J Respir Crit Care Med. 1995;152(5):1673–89. http://dx.doi.org/10.1164/ajrccm.152.5.7582313

28. Pevernagie DA, Stanson A, Sheedy 2nd P, Daniels BK, Shepard Jr JW. Effects of body position on the upper airway of patients with obstructive sleep apnea. Am J Respir Crit Care Med. 1995;152(1):179–85. http://dx.doi.org/10.1164/ajrccm.152.1.7599821

29. Tsukii S, Isono S, Ishikawa T, Yamashiro Y, Tsutami K, Nishino T. Anatomical balance of the upper airway and obstructive sleep apnea. J Am Soc Anesthesiol. 2008;108(6):1009–15. http://dx.doi.org/10.1097/ALN.0b013e318173f103

30. Redolfi S, Yumo D, Ruttanaumpawan P, Yau B, Su M-C, Lam J, et al. Relationship between overnight rostral fluid shift and obstructive sleep apnea in nonobese men. Am J Respir Crit Care Med. 2009;179(3):241–6. http://dx.doi.org/10.1164/rccm.200807-1076OC

31. Somers VK, White DP, Amin R, Abraham WT, Costa F, Culebras A, et al. Sleep apnea and cardiovascular disease: An American Heart Association/American College of Cardiology Foundation scientific statement from the American Heart Association Council for High Blood Pressure Research Professional Education Committee, Council on Clinical Cardiology, Stroke Council, and Council on Cardiovascular Nursing in collaboration with the National Heart, Lung, and Blood Institute National Center on Sleep Disorders Research (National Institute of Health). J Am Coll Cardiol. 2008;52(8):686–717. http://dx.doi.org/10.1016/j.jacc.2008.05.002

32. Briençon-Marjollet A, Weiszenstein M, Henri M, Thomas A, Godin-Ribout D, Polak J. The impact of sleep disorders on glucose metabolism: Endocrine and molecular mechanisms. Diabetol Metab Syndr. 2015;7(1):1–16. http://dx.doi.org/10.1186/s13098-015-0018-3

33. Subramani Y, Singh M, Wong J, Kushida CA, Malhotra A, Chung F. Understanding phenotypes of obstructive sleep apnea: Applications in anesthesia, surgery, and perioperative medicine. Anesth Analg. 2017;124(1):179. http://dx.doi.org/10.1213/ANE.0000000000001546

34. Eckert DJ, White DP, Jordan AS, Malhotra A, Wellman A. Defining phenotypic causes of obstructive sleep apnea. Identification of novel therapeutic targets. Am J Respir Crit Care Med. 2013;188(8):996–1004. http://dx.doi.org/10.1164/rccm.201303-0448OC

35. Aishah A, Eckert DJ. Phenotypic approach to pharmacotherapy in the management of obstructive sleep apnoea. Curr Opin Pulm Med. 2019;25(6):594–601. http://dx.doi.org/10.1097/MCP.0000000000000628

36. Gray EL, McKenzie DK, Eckert DJ. Obstructive sleep apnea without obesity is common and difficult to treat: Evidence for a distinct pathophysiological phenotype. J Clin Sleep Med. 2017;13(1):81–8. http://dx.doi.org/10.5664/jcsm.6394

37. Younges M, Ostrowski M, Atkar R, Laprairie J, Siemens A, Hanly P. Mechanisms of breathing instability in patients with obstructive sleep apnea. J Appl Physiol. 2007;103(6):1929–41. http://dx.doi.org/10.1152/japplphysiol.00561.2007

38. Mir S, Wong J, Ryan CM, Bellingham G, Singh M, Waseem R, et al. Concomitant benzodiazepine and...
opioids decrease sleep apnoea risk in chronic pain patients. ERJ Open Res. 2020;6(3):00093–2020. http://dx.doi.org/10.1183/23120541.00093-2020

39. Eckert DJ, Owens RL, Kehlmann GB, Wellman A, Rahangdale S, Yim-Yeh S, et al. Eszopiclone increases the respiratory arousal threshold and lowers the apnoea/hypopnoea index in obstructive sleep apnea patients with a low arousal threshold. Clin Sci. 2011;120(12):505–14. http://dx.doi.org/10.1042/CS20100588

40. Altreet TJ, Chung F, Chan MT, Eckert DJ. Vulnerability to postoperative complications in obstructive sleep apnea: Importance of phenotypes. Anesth Analg. 2021;132(5):1328–37. http://dx.doi.org/10.1213/ANE.0000000000005390

41. Sands SA, Edwards BA, Terrill PI, Taranto-Montemurro L, Azarbarzin A, Marques M, et al. Phenotyping pharyngeal pathophysiology using polysomnography in patients with obstructive sleep apnea. Am J Respir Crit Care Med. 2018;197(9):1187–97. http://dx.doi.org/10.1164/rccm.201707-1435OC

42. Messineo L, Taranto-Montemurro L, Azarbarzin A, Oliveira Marques MD, Calianese N, White DP, et al. Breath-holding as a means to estimate the loop gain contribution to obstructive sleep apnoea. J Physiol. 2018;596(17):4043–56. http://dx.doi.org/10.1113/jp276206

43. Chung F, Memtsoudis SG, Ramachandran SK, Nagappa M, Opperer M, Cozowicz C, et al. Society of anesthesia and sleep medicine guidelines on preoperative screening and assessment of adult patients with obstructive sleep apnea. Anesth Analg. 2016;123(2):452. http://dx.doi.org/10.1213/ANE.000000000001416

44. Chung F, Liao P, Farney R. Correlation between the STOP-Bang score and the severity of obstructive sleep apnea. Anesthesiology. 2015;122(6):1436–7. http://dx.doi.org/10.1097/ALN.0000000000000665

45. Chung F, Yegneswaran B, Liao P, Chung SA, Vairavanathan S, Islam S, et al. STOP questionnaire: A tool to screen patients for obstructive sleep apnea. J Am Soc Anesthesiol. 2008;108(5):812–21. http://dx.doi.org/10.1097/01.jsa.0000000000000634

46. Nagappa M, Liao P, Wong J, Aukley D, Ramachandran SK, Memtsoudis S, et al. Validation of the STOP-Bang questionnaire as a screening tool for obstructive sleep apnea among different populations: A systematic review and meta-analysis. PLoS One. 2015;10(12):e0143697. http://dx.doi.org/10.1371/journal.pone.0143697

47. Nagappa M, Wong J, Singh M, Wong DT, Chung F. An update on the various practical applications of the STOP-Bang questionnaire in anesthesia, surgery, and perioperative medicine. Curr Opin Anaesthesiol. 2017;30(1):118. http://dx.doi.org/10.1097/ACO.0000000000000426.

48. Seet E, Chua M, Liaw CM. High STOP-BANG questionnaire scores predict intraoperative and early postoperative adverse events. Singapore Med J. 2015;56(4):212. http://dx.doi.org/10.11622/smedj.2015034

49. Kapur VK, Auckley DH, Chowdhuri S, Kuhlmann DC, Mehra R, Ramar K, et al. Clinical practice guideline for diagnostic testing for adult obstructive sleep apnea: An American Academy of Sleep Medicine clinical practice guideline. J Clin Sleep Med. 2017;13(3):479–504. http://dx.doi.org/10.5664/jcsm.6506

50. Vaughn BV, Giannanza P. Technical review of polysomnography. Chest. 2008;134(6):1310–9. http://dx.doi.org/10.1378/chest.08-0812

51. Jonas DE, Amick HR, Feltner C, Weber RP, Arvanitis M, Stine A, et al. Screening for obstructive sleep apnea in adults: Evidence report and systematic review for the US Preventive Services Task Force. Jama. 2017;317(4):415–33. http://dx.doi.org/10.1001/jama.2016.19635

52. Saletu MT, Kotzian ST, Schwarzinger A, Haider S, Spatt J, Saletu B. Home sleep apnea testing is a feasible and accurate method to diagnose obstructive sleep apnea in stroke patients during in-hospital rehabilitation. J Clin Sleep Med. 2018;14(9):1495–501. http://dx.doi.org/10.5664/jcsm.7322

53. Szeto B, Vertosick EA, Ruiz K, Tokita H, Vickers A, Assel M, et al. Outcomes and safety among patients with obstructive sleep apnea (OSA) undergoing cancer surgery procedures in a free-standing ambulatory surgical facility. Anesth Analg. 2019;129(2):360. http://dx.doi.org/10.1213/ANE.000000000001411

54. Rosero EB, Joshi GP. Outcomes of sleep apnea surgery in outpatient and inpatient settings. Anesth Analg. 2021;123(5):1215–22. http://dx.doi.org/10.1213/ANE.0000000000005394

55. Ravesloot MJ, De Raaff CA, Van De Beek MJ, Benoist LB, Beyers J, Corso RM, et al. Perioperative care of patients with obstructive sleep apnea undergoing upper airway surgery: A review and consensus recommendations. JAMA Otolaryngol Neck Surg. 2019;145(8):751–60. http://dx.doi.org/10.1001/jamaoto.2019.1448

56. Mutter TC, Chateau D, Moffatt M, Ramsey C, Roos LL, Kryger M. A matched cohort study of postoperative outcomes in obstructive sleep apnea: Could preoperative diagnosis and treatment prevent complications? Anesthesiology. 2014;121(4):707–18. http://dx.doi.org/10.1097/ALN.0000000000000407

57. Abdelattar ZM, Hendren S, Wong SL, Campbell Jr DA, Ramachandran SK. The impact of untreated obstructive sleep apnea on cardiopulmonary complications in general and vascular surgery: A cohort study. Sleep. 2015;38(8):1205–10. http://dx.doi.org/10.5665/sleep.4892

58. Nagappa M, Mokhlesi B, Wong J, Wong DT, Kaw R, Chung F. The effects of continuous positive airway pressure on postoperative outcomes in obstructive sleep apnea patients undergoing surgery: A systematic review and meta-analysis. Anesth Analg. 2015;120(5):1013–23. http://dx.doi.org/10.1213/ANE.000000000000634

59. Ramakrishna G, Sprung J, Ravi BS, Chandrasekaran K, McGoon MD. Impact of pulmonary hypertension on the outcomes of noncardiac surgery: Predictors of perioperative
morbidity and mortality. J Am Coll Cardiol. 2005;45(10):1691–9. http://dx.doi.org/10.1016/j.jacc.2005.02.055

60. Kaw R, Bhateja P, y Mar HP, Hernandez AV, Ramaswamy A, Deshpande A, et al. Postoperative complications in patients with unrecognized obesity hypventilation syndrome undergoing elective noncardiac surgery. Chest. 2016;149(1):84–91. http://dx.doi.org/10.1378/chest.14-3216

61. Chung F, Zhou L, Liao P. Parameters from preoperative overnight oximetry predict postoperative adverse events. Minerva Anestesiol. 2014;80(10):1084–95.

62. Meoli A, Rosen C, Kristo D, Kohrman M, Gooneratne N, Aguillard R. Clinical Practice Review Committee American Academy of Sleep Medicine. Upper airway management of the adult patient with obstructive sleep apnea in the perioperative period: Avoiding complications. Sleep. 2003;26:1060–5. http://dx.doi.org/10.1093/sleep/26.8.1060

63. Nagappa M, Wong DT, Cozowicz C, Ramachandran SK, Memtsoudis SG, Chung F. Is obstructive sleep apnea associated with difficult airway? Evidence from a systematic review and meta-analysis of prospective and retrospective cohort studies. PLoS One. 2018;13(10):e0204904. http://dx.doi.org/10.1371/journal.pone.0204904

64. Benumof JL. Obesity, sleep apnea, the airway and anesthetic considerations. Curr Opin Anesthesiol. 2004;17(1):21–30. http://dx.doi.org/10.1097/00001053-200402000-00005

65. Isono S, Warner DS, Warner MA. Obstructive sleep apnea of the adult patient with obstructive sleep apnea in the perioperative period: Avoiding complications. Sleep. 2003;26:1060–5. http://dx.doi.org/10.1093/sleep/26.8.1060

66. Apfelbaum JL, Hagberg CA, Caplan RA, Blitt CD, Connis RT, Nickinovich DG, et al. Practice guidelines for management of the difficult airway: An updated report by the American Society of Anesthesiologists Task Force on Management of the Difficult Airway. Anesthesiology. 2013;118(2):251–70. http://dx.doi.org/10.1097/ALN.0b013e31827773b2

67. Seet E, Chung F. Management of sleep apnea in adult patients with obstructive sleep apnea. Anesthesiology. 2016;122(1):145–51. http://dx.doi.org/10.1213/ANE.0000000000000841

68. Seet E, Nagappa M, Wong DT. Airway management in surgical patients with obstructive sleep apnea. Anesth Analg. 2021;132(5):1321–7. http://dx.doi.org/10.1213/ANE.00000000005298

69. Dong WT, Dallaire A, Singh KP, Madhusudan P, Jackson T, Singh M, et al. High-flow nasal oxygen improves safe apnea time in morbidly obese patients undergoing general anesthesia: A randomized controlled trial. Anesth Analg. 2019;129(4):1130–6. http://dx.doi.org/10.1213/ANE.00000000003966

70. Deegan PC, Mulloy E, McNicholas WT. Topical oropharyngeal anesthesia in patients with obstructive sleep apnea. Am J Respir Crit Care Med. 1995;151(4):1108–12. http://dx.doi.org/10.1164/ajrccm/151.4.1108

71. Hillman DR, Chung F. Anaesthetic management of sleep‐disordered breathing in adults. Respirology. 2017;22(2):230–9. http://dx.doi.org/10.1111/resp.12967

72. Eastwood PR, Platt PR, Shepherd K, Maddison K, Hillman DR. Collapsibility of the upper airway at different concentrations of propofol anesthesia. J Am Soc Anesthesiol. 2005;103(3):470–7. http://dx.doi.org/10.1097/00005452-200509000-00007

73. Hutchison R, Rodriguez L. Capnography and respiratory depression. AJN Am J Nurs. 2008;108(2):35–9. http://dx.doi.org/10.1097/00001503-200802000-00005

74. Naqvi SY, Rabiei AH, Maltenfort MG, Restrepo C, Viscusi ER, Parvizi J, et al. Perioperative complications in patients with sleep apnea undergoing total joint arthroplasty under various types of anesthesia: A population‐based study of perioperative outcomes. Reg Anesth Pain Med. 2013;38(4):274–81. http://dx.doi.org/10.1097/AAP.0b013e31828d1d173

75. Memtsoudis SG, Stundner O, Rasul R, Sun X, Chiu Y-L, Fleischut P, et al. Sleep apnea and total joint arthroplasty under various types of anesthesia: A population-based study of perioperative outcomes. Reg Anesth Pain Med. 2013;38(4):274–81. http://dx.doi.org/10.1097/AAP.0b013e31828d1d173

76. Memtsoudis SG, Stundner O, Rasul R, Sun X, Chiu Y-L, Fleischut P, et al. Sleep apnea and total joint arthroplasty under various types of anesthesia: A population-based study of perioperative outcomes. Reg Anesth Pain Med. 2013;38(4):274–81. http://dx.doi.org/10.1097/AAP.0b013e31828d1d173

77. Chung F, Liao P, Yegneswaran B, Shapiro CM, Kang W. Postoperative changes in sleep‐disordered breathing and sleep architecture in patients with obstructive sleep apnea. Anesthesiology. 2014;120(2):287–98. http://dx.doi.org/10.1097/ALN.0000000000000040

78. Fouladpour N, Jesudoss R, Bolden N, Shamaan Z, Auckley D. Perioperative complications in obstructive sleep apnea patients undergoing surgery: A review of the legal literature. Anesth Analg. 2016;122(1):145–51. http://dx.doi.org/10.1213/ANE.0000000000000841

79. Hafeez KR, Tuteja A, Singh M, Wong DT, Nagappa M, Chung F, et al. Perioperative complications with neuromuscular blocking drugs and/or reversal agents in obstructive sleep apnea patients: A systematic review. BMC Anesthesiol. 2018;18(1):1–11. http://dx.doi.org/10.1186/s12871-018-0549-x

80. Meng T, Zhong Z, Meng L. Impact of spinal anaesthesia vs. general anaesthesia on peri-operative outcome in lumbar spine surgery: A systematic review and meta-analysis of randomised, controlled trials. Anaesthesia. 2017;72(3):391–401. http://dx.doi.org/10.1111/anae.13702

81. Macfarlane AJ, Prasad GA, Chan VW, Brull R. Does regional anaesthesia improve outcome after total knee arthroplasty? Clin Orthop Relat Res. 2009;467(9):2379–402. http://dx.doi.org/10.1007/s11999-008-0666-9

82. Gan TJ. Poorly controlled postoperative pain: Prevalence, consequences, and prevention. J Pain Res. 2017;10:2287. http://dx.doi.org/10.2147/JPR.S144066

83. Gupta K, Nagappa M, Prasad A, Abrahamyan L, Wong J, Weingarten TN, et al. Risk factors for opioid-induced
respiratory depression in surgical patients: A systematic review and meta-analyses. BMJ Open. 2018;8(12):e024086. http://dx.doi.org/10.1136/bmjopen-2018-024086

84. Doufas AG, Tian L, Davies MF, Warby SC. Nocturnal intermittent hypoxia is independently associated with pain in subjects suffering from sleep-disordered breathing. Anesthesiology. 2013;119(5):1149–62. http://dx.doi.org/10.1097/ALN.0b013e318a951fc

85. Turan A, You J, Egan C, Fu A, Khanna A, Eshraghi Y, et al. Chronic intermittent hypoxia is independently associated with reduced postoperative opioid consumption in bariatric patients suffering from sleep-disordered breathing. PLoS One. 2015;10(5):e0127809. http://dx.doi.org/10.1371/journal.pone.0127809

86. Blake D, Yew C, Donnan G, Williams D. Postoperative analgesia and respiratory events in patients with symptoms of obstructive sleep apnoea. Anaest Intensive Care. 2009;37(5):720–5. http://dx.doi.org/10.1111/j.1740-8994.2009.01005.x

87. Kehlet H, Werner MU. Role of paracetamol in the acute pain management. Drugs. 2003;63:15–22. http://dx.doi.org/10.2165/00003495-200363992-00004

88. Ong CK, Seymour RA, Lirk P, Merry AF. Combining paracetamol (acetaminophen) with nonsteroidal antiinflammatory drugs: A qualitative systematic review of analgesic efficacy for acute postoperative pain. Anesth Analg. 2010;110(4):1170–9. http://dx.doi.org/10.1213/ANE.0b013e3181c9281

89. Wickerts L, Brattwall M, Jakobsson J. Coxibs: Is there a benefit when compared to traditional non-selective NSAIDs in postoperative pain management? Minerva Anestesiol. 2011;77(11):1084–98.

90. Waldron N, Jones C, Gan T, Allen T, Habib A. Impact of perioperative dexamethasone on postoperative analgesia and side-effects: Systematic review and meta-analysis. Br J Anaesth. 2013;110(2):191–200. http://dx.doi.org/10.1093/bja/aes431

91. Albrecht E, Kern C, Kirkham K. A systematic review and meta-analysis of perineural dexamethasone for peripheral nerve blocks. Anaesthesia. 2015;70(1):71–83. http://dx.doi.org/10.1111/anae.12823

92. Czowicz C, Chung F, Doufas AG, Nagappa M, Memtsoudis SG. Opioids for acute pain management in patients with obstructive sleep apnea: A systematic review. Anesth Analg. 2018;127(4):988–1001. http://dx.doi.org/10.1213/ANE.0000000000003549

93. American Society of Anesthesiologists Task Force on Neuraxial Opioids. Practice guidelines for the prevention, detection, and management of respiratory depression associated with neuraxial opioid administration. J Am Soc Anesthesiol. 2009;110(2):218–30. http://dx.doi.org/10.1097/ALN.0b013e31818ec946.

94. Cavalcante AN, Sprung J, Schroeder DR, Weingarten TN. Multimodal analgesic therapy with gabapentin and its association with postoperative respiratory depression. Anesth Analg. 2017;125(1):141–6. http://dx.doi.org/10.1213/ANE.0000000000001719

95. Weingarten TN, Jacob AK, Njathi CW, Wilson GA, Sprung J. Multimodal analgesic protocol and postanesthesia respiratory depression during phase I recovery after total joint arthroplasty. Reg Anesth Pain Med. 2015;40(4):330–6. http://dx.doi.org/10.1097/AAP.0000000000000257

96. Neill AM, Angus SM, Sajkov D, McEvoy RD. Effects of sleep posture on upper airway stability in patients with obstructive sleep apnea. Am J Respir Crit Care Med. 1997;155(1):199–204. http://dx.doi.org/10.1164/ajrccm.155.1.9001312

97. Penzel T, Möller M, Becker HF, Knaack L, Peter J-H. Effect of sleep position and sleep stage on the collapsibility of the upper airways in patients with sleep apnea. Sleep. 2001;24(1):90–5. http://dx.doi.org/10.1093/sleep/24.1.90

98. Chung SA, Yuan H, Chung F. A systematic review of obstructive sleep apnea and its implications for anesthesiologists. Anesth Analg. 2008;107(5):1543–63. http://dx.doi.org/10.1213/ane.0b013e318187c83a

99. Lam T, Singh M, Yadollahi A, Chung F. Is perioperative fluid and salt balance a contributing factor in postoperative worsening of obstructive sleep apnea? Anesth Analg. 2016;122(5):1335–9. http://dx.doi.org/10.1213/ANE.0000000000001169

100. Isono S, Tanaka A, Nishino T. Lateral position decreases collapsibility of the passive pharynx in patients with obstructive sleep apnea. J Am Soc Anesthesiol. 2002;97(4):780–5. http://dx.doi.org/10.1097/00000542-200204000-00006

101. Liao P, Wong J, Singh M, Wong DT, Islam S, Andr Awes M, et al. Postoperative oxygen therapy in patients with OSA: A randomized controlled trial. Chest. 2017;151(3):597–611. http://dx.doi.org/10.1016/j.chest.2016.12.005

102. Liao P, Luo Q, Elsaid H, Kang W, Shapiro CM, Chung F. Perioperative auto-titrated continuous positive airway pressure treatment in surgical patients with obstructive sleep apnea: A randomized controlled trial. Anesthesiology. 2013;119(4):837–47. http://dx.doi.org/10.1097/00000542-201208000-00006

103. Suen C, Tong J, Warsame K, Subramani Y, Panzarella T, Waseem R, et al. Perioperative adherence to continuous positive airway pressure and its effect on postoperative nocturnal hypoxemia in obstructive sleep apnea patients: A prospective cohort study. BMC Anesthesiol. 2021;21(1):1–10. http://dx.doi.org/10.1186/s12871-021-01371-0

104. O’Gorman SM, Gay PC, Morgenhalter TI. Does autotitrating positive airway pressure therapy improve postoperative outcome in patients at risk for obstructive sleep apnea syndrome?: A randomized controlled clinical trial. Chest. 2013;144(1):72–8. http://dx.doi.org/10.1378/chest.12-0989

105. Gali B, Whalen FX, Schroeder DR, Gay PC, Plevak DJ. Identification of patients at risk for postoperative respiratory complications using a preoperative obstructive sleep apnea...
screening tool and postanesthesia care assessment. J Am Soc Anaesthesiol. 2009;110(4):869–77. http://dx.doi.org/10.1097/ALN.0b013e31819b5d70

106. Khanna AK, Bergese SD, Jungquist CR, Morimatsu H, Uezono S, Lee S, et al. Prediction of opioid-induced respiratory depression on inpatient wards using continuous capnography and oximetry: An international prospective, observational trial. Anesth Analg. 2020;131(4):1012. http://dx.doi.org/10.1213/ANE.0000000000004788

107. Subramani Y, Nagappa M, Wong J, Patra J, Chung F. Death or near-death in patients with obstructive sleep apnoea: A compendium of case reports of critical complications. Br J Anaesth. 2017;119(5):885–99. http://dx.doi.org/10.1093/bja/aex341

108. Lee LA, Caplan RA, Stephens LS, Posner KL, Terman GW, Voepel-Lewis T, et al. Postoperative opioid-induced respiratory depression: A closed claims analysis. Anesthesiology. 2015;122(3):659–65. http://dx.doi.org/10.1097/ALN.0000000000000564

109. Chung F, Wong J, Mestek ML, Niebel KH, Lichtenhal P. Characterization of respiratory compromise and the potential clinical utility of capnography in the post-anesthesia care unit: A blinded observational trial. J Clin Monit Comput. 2020;34(3):541–51. http://dx.doi.org/10.1007/s10877-019-00333-9