

Update on the perioperative management of obstructive sleep apnea adult patients: a narrative review

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Abstract

Obstructive Sleep apnea (OSA) is the most frequently encountered sleep disorder. It is characterized by repetitive and intermittent closure of the upper airway and is associated with significant predictable peri-operative cardio-respiratory co-morbidities. This pathology is under-diagnosed, even though it can be encountered in a third of the surgical population. Its complexity and heterogeneity make the perioperative management of those patients a challenge and requires adaptation. This article describes the pathophysiology of the condition, and its perioperative management. It revisits management algorithms and care pathways, to provide the reader with up-to-date information for the improvement of patient care.

Keywords: Obstructive sleep apnea, perioperative management, anesthetic management, airway.

Introduction

The Obstructive Sleep apnea-hypopnea (OSA) syndrome is a group of disorders characterized by a transient decrease in or interruption of ventilation during sleep. The prevalence of OSA is constantly increasing¹. This growth is directly linked to the increase in the prevalence of obesity, and in life expectancy over the last decades. However, OSA is still largely underdiagnosed. For the surgical team, OSA is a challenging disorder. Indeed, OSA is established as an independent risk factor of perioperative complications, particularly cardiopulmonary ones^{2,3}, rendering the perioperative period very critical for those patients. Given the high cost of managing postoperative complications, OSA is a public health issue. Consequently, a particular attention should be

paid to the preoperative detection of the disorder, and to implementing structured care pathways to prevent some of the risks of undesirable outcomes, insofar as many studies have shown that the perioperative optimization of these patients improves postoperative morbidity and mortality⁴⁻⁶.

Groups as the American Society of Anesthesiologists (ASA)⁷, the Society for Ambulatory Anesthesia (SAMBA)⁶, and the Society of Anesthesia and Sleep Medicine (SASM)⁵ have produced recommendations, based on scientific evidence, to address the lack of perioperative care algorithms for those patients. Experts recommend preoperative screening, intraoperative tuning of the care plan, and postoperative follow-up, including close monitoring and the use of Continuous Positive Airway Pressure devices (CPAP) in selected patients.

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This narrative review aims at summarizing the current recommendations, to help perioperative clinicians, including anesthesiologists and general practitioners, enhancing the quality of management for these surgical patients before and after anesthesia, and, in the end, improve outcome.

Methodology

The literature that was relevant for the writing of this narrative review was collected using the PubMed® search engine and Google Scholar®. The following combination of keywords was endorsed by all the authors and used to perform the search: obstructive sleep apnea, perioperative management, anesthetic management, airway. The literature was browsed between 1985 and 2024. Only papers related to adults were retained in the initial list. Relevance was then decided based on the title of the publication and the content of its abstract.

Epidemiology

OSA is one of the most frequently encountered sleep disorders, with a high prevalence worldwide. It is estimated that nearly one billion people between 30- and 69-year-old suffer from this disability¹. This represents between 9 and 38% of adults (depending on the diagnosis standards), with moderate to severe cases accounting for up to 17% of the general adult population⁸. Considering the surgical population, it represents between 24 and 41% of people undergoing anesthesia⁹, with a drastically higher prevalence in bariatric surgery, reaching 70% of patients¹⁰. Depending on the sensitivity of diagnostic tools, the presence of an OSA syndrome is often missed¹¹. Given the fact that it predisposes to perioperative complications, missing the syndrome in surgical patients may generate considerable costs, with substantial consequences in terms of public health^{7,12}.

The underlying pathophysiology

OSA is a respiratory disorder characterized by a narrowing and repetitive closure of the upper airway during sleep^{13,14}. Physiologically, sleep suppresses the cognitive command of the respiratory center located in the brainstem. This provokes a decrease in the pharyngeal dilator muscles' tone, which are mainly the genioglossus muscle and the tensor of the soft palate¹⁵.

In susceptible patients, the collapse may cause obstruction, which can be partial and produce hypopnea, or complete and produce apnea. Obstruction leads to hypoventilation, hypercapnia, and hypoxia. In response to hypercapnia and hypoxia, a reflex originating in the carotid and

aorta chemoreceptors stimulates ventilatory control and induces, if the arousal threshold is reached, microarousals. The negative pharyngeal and thoracic pressure generated by the respiratory efforts against a closed upper airway in turn activates mechanoreceptors, inducing a muscle response to restrain the upper airway depression and closure^{13,16}. In OSA patients, there is a mismatch between the degree of the upper airway obstruction and the ventilatory response. The ventilatory response to hypoxia and hypercapnia is disproportionately larger than in non-OSA patients, inducing an overshoot in CO₂ partial pressure correction and hypocapnia. Hypocapnia then induces hypoventilation, upper airway muscle hypotonia and a secondary airway obstruction, a phenomenon called the 'loop gain', which self-perpetuates episodes of apnea/hypopnea¹⁷. A dysregulation of the ventilatory response in some OSA patients is thought to be linked to alterations in serotonin neurotransmission, which is known to play a key role in ventilatory stimulation¹⁸. Efforts to fight against airway obstruction provoke repetitive awakenings and destroy the sleep architecture¹⁶. At the same time, hypoxia stimulates the sympathetic nervous system, generating an inflammatory cascade linked to oxidative stress (Figure 1). This is responsible for the progressive development of several comorbidities¹⁵.

The risk factors

Factors contributing to pharyngeal collapse can be classified as non-modifiable or modifiable. Non-modifiable factors include age, gender, and heredity. The incidence of OSA increases with age after 60 years of age¹⁹. In Belgium, it is estimated that the population aged 65 years and over will rise from 19% in 2019 to 26.9% in 2050²⁰, hence contributing to the increase in the prevalence of OSA. OSA is twice more frequent in males than in females, while this difference tends to disappear after menopause. Heredity is a robust predisposing factor^{21,22}. Some critical genetic traits of importance for determining the occurrence of OSA are craniofacial conformation, body fat distribution, upper airway tissue composition, and respiratory control function²³. Obesity is the main modifiable risk factor of OSA. Again, the world global obesity epidemic contributes to the increasing prevalence of OSA. The proportion of people with a body mass index >30 Kg m⁻² has grown from 8.4% in 1980 to 20% in 2019 and is rising by approximately 2% every decade²⁰.

OSA phenotypes

Four main criteria categories have been proposed to define OSA phenotypes over the last few

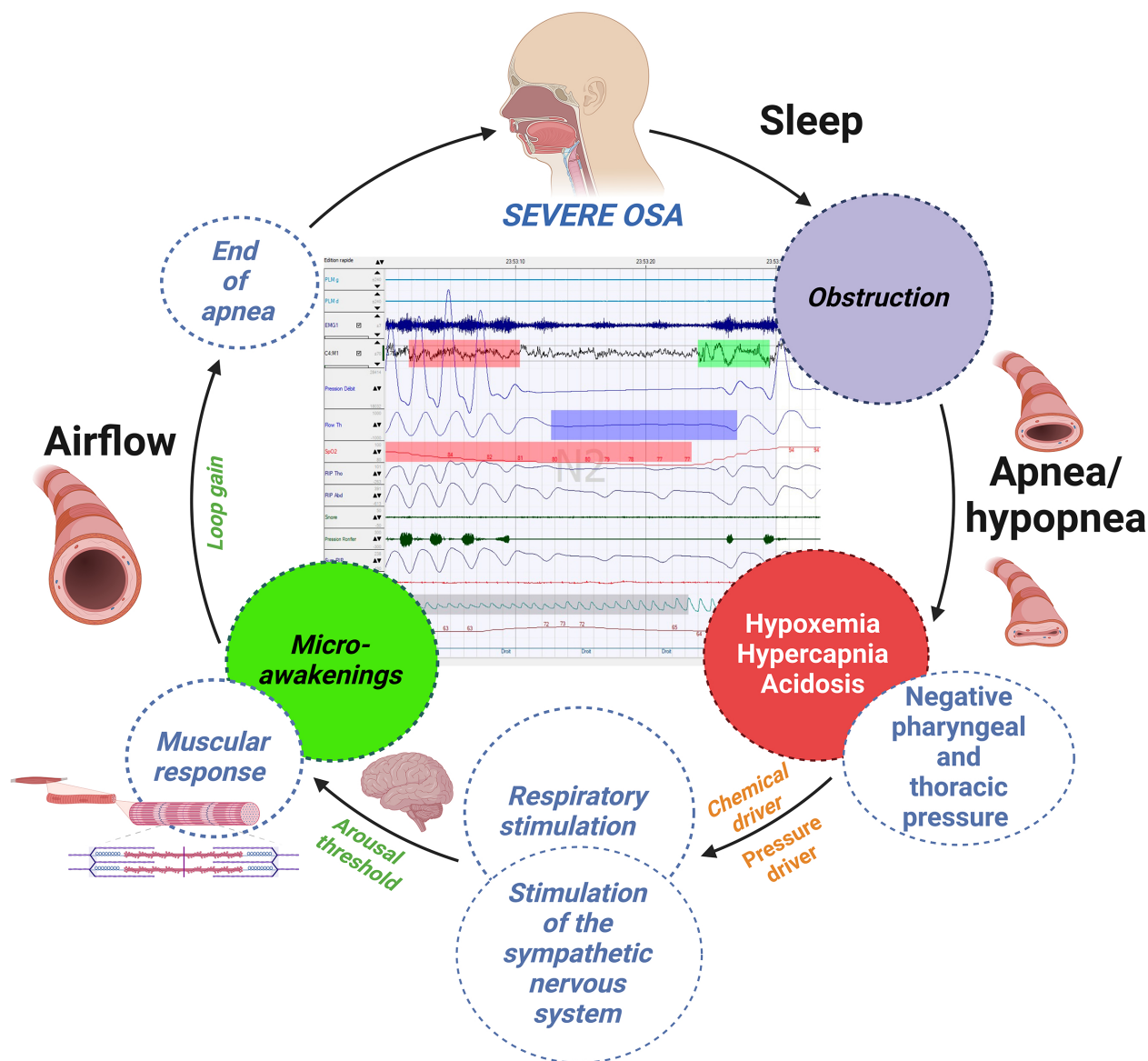


Fig. 1 — Description of the apnea-hypopnea cycle in the obstructive sleep apnea syndrome (OSA). The image in the center is an example of polysomnography in a severely affected OSA patient. It shows a phase of apnea causing desaturation and followed by microarousal and loop gain. This succession of elements can vary to different degrees in different patients.

decades^{23,24} (Figure 2). Some of those criteria are of an anatomical nature, and others are rather physiological. Distinguishing between phenotypes opens the door to an individualized treatment, and even more, to an individualized perioperative management.

The first criteria category relates to the anatomical vulnerability of the upper airway for obstruction. In this case, obesity exerts the main influence. It predisposes to substantial parapharyngeal fat deposit, which favors obstruction. Clinically, the importance of parapharyngeal fat deposit can be indirectly estimated through the measurement of the cervical circumference. A circumference >40 cm indicates the presence of a narrowing of the pharynx, and risk of collapse²⁵. In addition, abundant abdominal fat, by an upward displacement of the diaphragm and a decrease in pulmonary reserve,

and due to a mechanical coupling between the upper and lower airway structures, reduces caudal pharyngeal traction and narrows the upper airway²⁶. The craniofacial morphology is also a determinant of the permeability of the upper airway. A caudal position of the hyoid bone, an increase in the upper airway length, a tight mandible, and retrognathia may hinder pharyngeal opening. This morphology is more frequent in some ethnic groups, such as in Asians^{27,28}. The sleep posture and sleep stage are additional factors influencing the clinical expression of OSA. OSA can be favored by the supine position, either in isolation, when the apnea/hypopnea index (AHI) is <5 in the non-supine position and becomes twice as high and >5 in the supine position, or predominantly, when AHI is always >5 and twice as high in the supine as in the non-supine position. If posture exerts an influence,

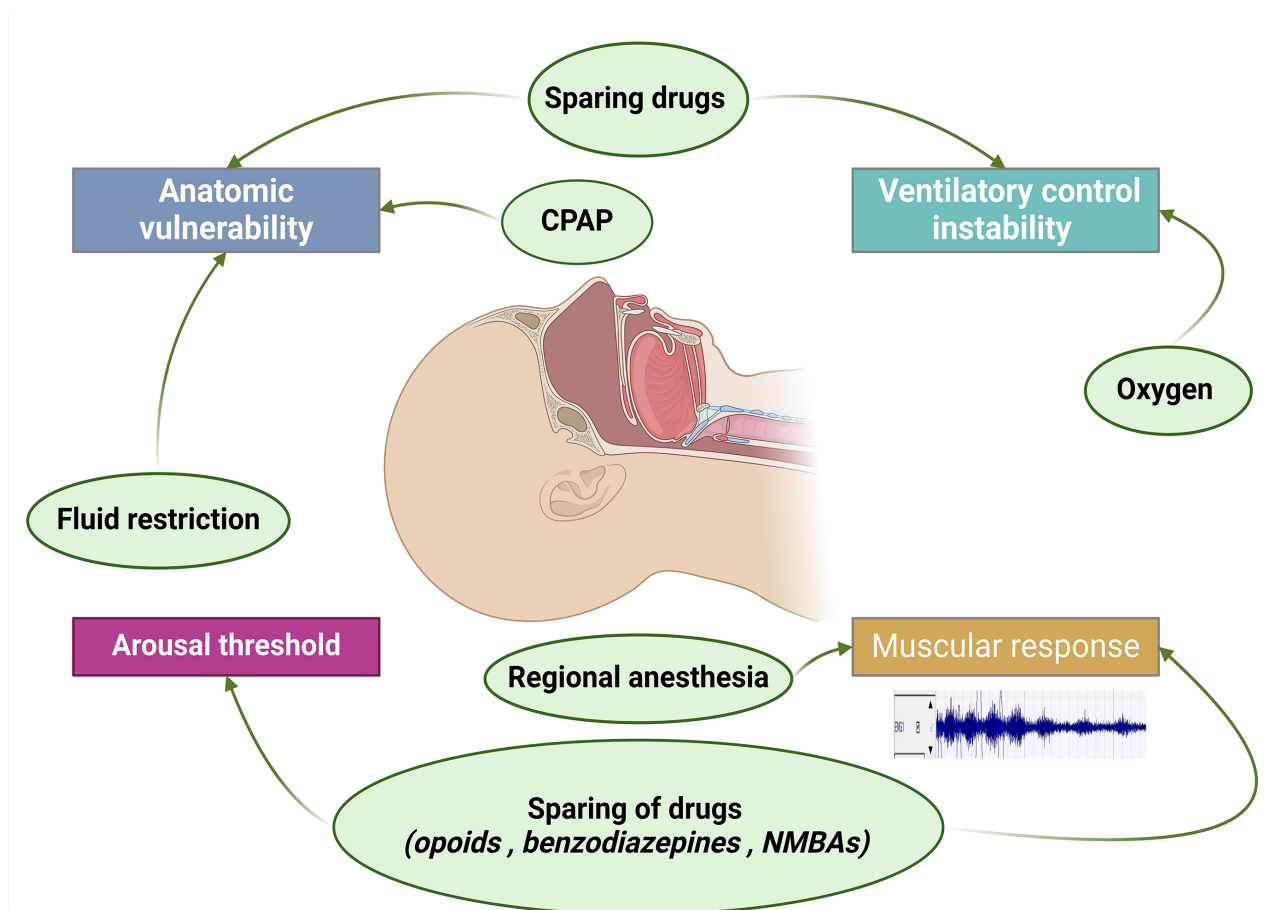


Fig. 2 — Categories of criteria to define obstructive sleep apnea syndrome phenotypes, and possible treatment options as a function of existing anomalies (see text for details). An anatomic vulnerability is best thwarted by fluid restriction, CPAP (continuous positive airway pressure), and judicious use of hypnotics, sedatives, and opioids (drug sparing). Ventilatory control instability is best approached with oxygen therapy and drug sparing. Impaired arousal threshold and upper airway dilator muscles' response also necessitate drug sparing. CPAP = continuous positive airway pressure. NMBAs = neuromuscular blocking agents.

positional therapy should be considered (either lateral or sitting position during sleep) in addition to the other treatments²⁹. Airway collapse can be seen during both rapid eye movement (REM) and non-REM sleep phases. However, it has been shown that during the REM phase, the propensity for airway collapse is higher (REM sleep atonia), introducing an entity known as REM sleep-related OSA³⁰.

The second category relates to the respiratory arousal threshold, described as the level of ventilatory drive triggering arousal from sleep. Two types of respiratory arousal threshold can be distinguished³¹. The “low arousal threshold” corresponds arousal following a low ventilatory drive, triggering an early stimulation of the inspiratory motor neurons of the upper airway to open it. Patients with a low arousal threshold present frequent awakening, and disorganized sleep. In that case, the transition to deep sleep stages, where the respiratory control of the upper airway patency is better, is impeded, and sleep is less restorative. Those patients frequently suffer from diurnal fatigue. A low arousal threshold is frequently seen in patients with mild to moderate

OSA. In contrast, a “high arousal threshold” is associated to a reduced response of the ventilatory drive to hypoxia and hypercapnia. In that case, awakenings are less frequent. A high arousal threshold is more frequently seen in patients with moderate to severe OSA. As described below, the perioperative management is different in patients with low and those with high arousal threshold. Unfortunately, it is currently not possible to discriminate the ‘high’ from the ‘low’ arousal threshold patient preoperatively, based on clinical arguments only. Polysomnography (PSG) is necessary for this, knowing that patients with a ‘high’ arousal threshold are at greater risk of postoperative complications.

The third category relates to the stability of ventilatory control mechanisms, referred to as the respiratory control loop in response to hypoxia and hypercapnia, and in relation with the above-mentioned loop gain¹³. Some patients exhibit a poor matching between the magnitude of hypoxia and hypercapnia, on the one hand, and the associated respiratory response, on the other hand. Patients with a high loop gain have early anarchic hyperventilation in response to hypoxia and

hypercapnia, secondary to an excessive activation of the pharyngeal and respiratory muscles. This may result in hypocapnia and secondary central apnea. As mentioned above, a dysregulation of ventilatory control might be linked to alterations in serotonin neurotransmission in some patients¹⁸.

The last category of criteria involves the muscular response capacity of the upper airway, mainly the one of the genioglossus muscles. The muscular response is activated through a reflex loop, which comprises afferences to the brainstem from mechanoreceptors sensitive to negative pressure in the oropharynx³² and from chemoreceptors sensitive to hypercapnia and hypoxia³³, and efferences from the brainstem. One third of OSA patients suffer from an impaired reactivity of the oropharynx dilator muscles³⁴.

Statistical analysis

OSA is an independent cardiovascular risk factor. This is linked to episodes of repeated intermittent hypoxia, which causes numerous dysregulations, and whose frequency is directly linked to the severity of OSA³⁵. Chronically elevated arterial blood pressure is common in OSA. Indeed, 25% of hypertensive patients suffer from OSA, a proportion that can to over 80% in patients with refractory hypertension and primary hyperaldosteronism^{36–38}. A chronic exposure to intermittent hypoxia causes sympathetic hyperstimulation. It stimulates the renal, adrenal and peripheral chemoreceptors, resulting in a change in circulating hormones³⁹. The stimulation of the carotid glomi causes an overproduction in catecholamines in response to hypoxia. This leads to an increase in vascular tone (vasoconstriction) and vascular remodeling (rigidity), as well as an increase in heart rate³⁹. In addition, inspiration efforts against an impermeable oropharynx (known as the Muller's maneuver) provoke deep negative thoracic pressures, and an enlargement of the myocardial and vascular walls, which favors atrial fibrillation and aortic aneurysms⁴⁰. The renal sympathetic stimulation leads to an increase in angiotensin II circulating levels, and therefore activates the adrenal cortex, which in turn secretes aldosterone and induces sodium retention with potassium excretion. It also accentuates vasoconstriction. In OSA patients, the circulating levels of angiotensin II and aldosterone are higher than in the healthy population, depending on the severity of OSA³⁶. The renin-angiotensin-aldosterone system is thought to be the main cause of refractory hypertension in OSA³⁹. This fluid shift also increases pharyngeal oedema and therefore the risk of apnea, creating a vicious circle. Other

factors such as leptin or adipocytes themselves (which produce aldosterone) could be involved, but studies are currently underway.

Atherosclerosis occurs early and independently from the other cardiovascular risk factors. The pathophysiological tenants of atherosclerosis are closely interconnected with those of hypertension. They are mainly linked to endogenous vascular parietal changes. Intermittent hypoxemia is thought to have atherosclerotic potential when associated with a high-fat diet⁴¹. For example, there is a direct link between the degree of hypoxia, the thickness of the carotid intima-media, and the appearance of plaques in patients suffering from OSA without known cardiovascular disease⁴².

The oxidative stress caused by hypoxia associated with sympathetic hyperactivity leads to an increase in NF- κ B (nuclear factor κ B), which provokes an inflammatory cascade and an increase in circulating levels of C-reactive protein, interleukin 6 and 8, and TNF α ^{14,39}. In parallel with this mild systemic inflammation, the endothelin-1 system is also activated³⁹. These mechanisms cause endothelial dysfunction with remodeling, which results in a down-regulation of nitric oxide (NO) synthesis and therefore reduced vasodilation. Chronic inflammation and sympathetic hyperactivity also cause lipid, carbohydrate and liver changes. Neoglucogenesis and hepatic glycogenolysis are stimulated¹⁴. In addition, lipolysis is promoted by inflammation of the adipose tissues, leading to dyslipidemia. These cascades explain insulin resistance and the risk of non-alcoholic liver disease.

All these interrelated mechanisms explain why patients suffering from OSA are at higher risk of cardiovascular disease, including coronary artery disease, atrial fibrillation, systemic arterial hypertension, stroke, and abdominal aortic aneurysm.

OSA may be responsible for an increase in pulmonary arterial pressure. The development of pulmonary arterial hypertension in OSA, defined as a mean pulmonary arterial pressure >20 mmHg, a pulmonary arterial wedge pressure ≤ 15 mmHg, and pulmonary vascular resistance ≥ 3 Wood units, is attributable to the occurrence of negative intrathoracic pressure, and hypoxia/hypercapnia episodes. Inspiration against a closed glottis produces negative intrathoracic pressure and increases pulmonary arterial pressure. During the apnea cycle, variations in oxygen saturation cause rapid variations in pulmonary arterial pressure, although with no clinical consequences. Severe and prolonged hypoxemia induces acute hypoxic vasoconstriction of the pulmonary artery.

Hypercapnia, and therefore acidosis, potentiates this phenomenon. Finally, inspiration following apnea causes an increase in stroke volume and heart rate, which in turn leads to an increase in pulmonary arterial pressure⁴³. On the long term and in the absence of OSA treatment, this may have consequences on right heart functioning.

Finally, OSA is associated to a procoagulant state, which seems to be linked to an enhanced formation of platelet-leukocyte aggregates and to endothelial damage⁴⁴.

Preoperative assessment of obstructive sleep apnea patients

In the absence of a prior assessment, the ASA⁷ and the SASM⁵ recommend a massive preoperative screening in all patients undergoing elective surgery, given the high prevalence of OSA. The aim of this systematic screening is to detect severe OSA and evidence eventual comorbidities, and to guide perioperative management. Indeed, OSA-associated comorbidities make the bed of postoperative cardiopulmonary complications^{45–48}. However, a balance must be found between the desire to minimize postoperative complications and the responsible use of available resources.

Polysomnography (PSG) is the gold standard for OSA diagnosis. It allows calculating the AHI (number of episodes of apnea/hypopnea per hour), and the oxygen desaturation index (ODI, number of desaturation episodes per hour, a desaturation is characterized by a decrease in the mean oxygen saturation of $\geq 4\%$ that lasts for at least 10 seconds)⁴⁹. However, the cost and availability of PSG render a large and routine performance in all patients impossible. This limitation is slightly attenuated by the possibility to perform simplified ambulatory PSG to highlight eventual respiratory events during the night, or to perform nocturnal oximetry for measuring the ODI⁵⁰. During the pre-anesthesia visit, the anamnesis, clinical examination, and analysis of medical record are key and play an important role in OSA detection and identification of comorbidities. These elements allow the calculation of prediction scores, which indicate the probability for a given patient of suffering from OSA. The STOP-BANG score²⁵ is the most widely used and combines the evaluation of objective and subjective traits. This score includes 8 yes/no questions, including the presence of Snoring, Tiredness, Obstruction (apnea), hypertension, Body mass index $>35 \text{ Kg.m}^{-2}$, Age >50 years, Neck circumference $>40 \text{ cm}$, and male Gender. Each positive item scores 1 point. A score is <3 indicates a low risk of OSA, between 3 and 4 a moderate risk, and ≥ 5 a high risk of moderate to

severe OSA. If the score is ≥ 7 , the risk of severe OSA is very high. Other scores are in the same line, such as the P-SAP⁵¹, the Berlin questionnaire⁵², or the ASA checklist⁷. The DES-OSA score⁵³, introduced Deflandre and coworkers, is different in that it uses objective morphological elements only, allowing to get rid of the randomness nature of subjective traits (both personal and hetero-anamnestic ones). It includes 5 morphological criteria (Mallampati score, neck circumference, distance between the cricoid cartilage and the chin, body mass index and male gender). Each item is weighted between 1 and 3 points according to the values obtained for each patient. If the score is >7 , there is a high risk of having severe OSA. It is particularly good at detecting severe OSA patients⁵³. The STOP-BANG score⁵⁴ and the Berlin questionnaire appear to be more sensitive and therefore allow mass screening for all categories of OSA (mild, moderate, severe), whereas the DES-OSA is more specific for severe OSA⁵⁵ and is more discriminant for severe hypoxemic patients⁵⁵.

To refine the screening of OSA patients, multiple biomarkers are currently being evaluated/ explored^{56,57}. Based on the pathophysiology of OSA, it is possible to screen for blood biomarkers that are indicative of inflammation (e.g., C-reactive protein, interleukin-6, tumor necrosis factor- α), oxidative stress (cysteine), sympathetic activation (noradrenaline, renin-angiotensin system), metabolic activity (glycated hemoglobin, cholesterol), and endothelial dysfunction (endothelial cell specific molecule-1 or endocan). It is also possible to screen for biomarkers that are present in the end-tidal exhaled breath (e.g., nitric oxide indicative of bronchial inflammation)⁵⁸, as well as genetic biomarkers (e.g., microRNA, polymorphism of serotonin transporter gene¹⁸, and DNA methylation). Research into biomarkers is still in its early stages, and large-scale studies have yet to be carried out.

Screening with scores in elective surgery patients lead to OSA suspicion in approximately 25% of cases⁵⁹.

A suspicion of severe OSA should lead to the performance of a PSG, to confirm diagnosis and severity, and secondarily assess the tolerance to a CPAP treatment. Once PSG is done, the AHI serves to classify the disease severity, with an AHI >5 corresponding to mild, >15 to moderate, and >30 to severe OSA.

In the specific case of outpatient surgery, the upstream selection of eligible patients must be careful, and adapted care pathways should be set up for OSA patients. For the selection of eligible patients, several factors need to be considered, such

as the severity of OSA as assessed by the AHI or the predictive score, adherence to treatment in the perioperative period (CPAP), associated systemic diseases (controlled or not), type of surgery and its degree of emergency, considered anesthesia technique, and the need for postoperative opioids. Patient, family, and care givers' education is of utmost importance along the care pathway, particularly regarding compliance with CPAP. If OSA is suspected but without associated cardiopulmonary comorbidities, the procedure can take place without delay. Surgery will be postponed only in case of non-treated severe OSA and non-stabilized comorbidities. Time will be taken to install OSA-specific treatment and tolerance to it (CPAP, weight loss, orthosis prescription, ...), and optimization of comorbidities' treatment before proceeding to the intervention. Unfortunately, there is still no precisely defined timeframe for efficacy on comorbidities (high blood pressure, metabolic disorders, atrial fibrillation, ...) following the initiation of treatments, because studies are heterogeneous in this respect, and strong evidence

is missing⁶⁰. A delay of 6 months is frequently proposed⁶¹.

A decisional flow chart for the preoperative assessment and management of OSA patients is proposed in Figure 3, and for the special case of ambulatory surgery in Figure 4.

Intraoperative management of obstructive sleep apnea patients

Once severe OSA screening has been performed, the perioperative management is adapted to reduce the risk of postoperative morbidity and mortality. In this respect, the anesthetic technique must be chosen judiciously, taking account of concerned surgical procedure, and advantages and pitfalls of each considered technique. A pharmacologic premedication to reduce anxiety is seldom necessary. In particularly anxious patients, clonidine or another α_2 -agonist should be preferred. Benzodiazepines and gabapentin are not recommended, because they increase the risk of post-operative complications such as drowsiness, delirium, and respiratory infections⁶².

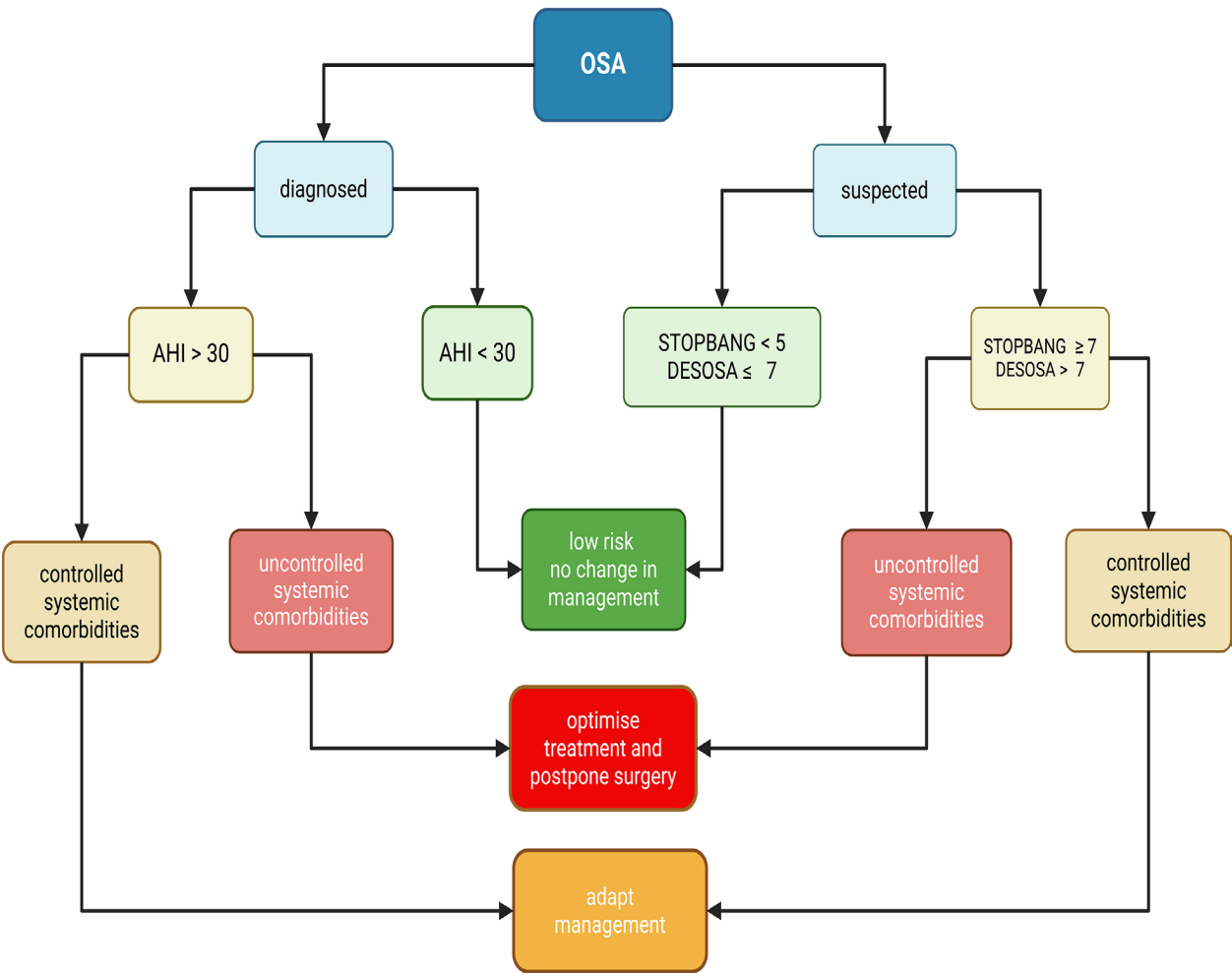


Fig. 3 — Decisional flow chart for the preoperative evaluation and management of OSA patients. Inspired by the guidelines produced by the ASA 7 and SASM 4,5. OSA= Obstructive Sleep Apnea-hypopnea; AHI = Apnea-Hypopnea Index; STOP-BANG = STOP-BANG screening score; DES-OSA = DES-OSA screening score.

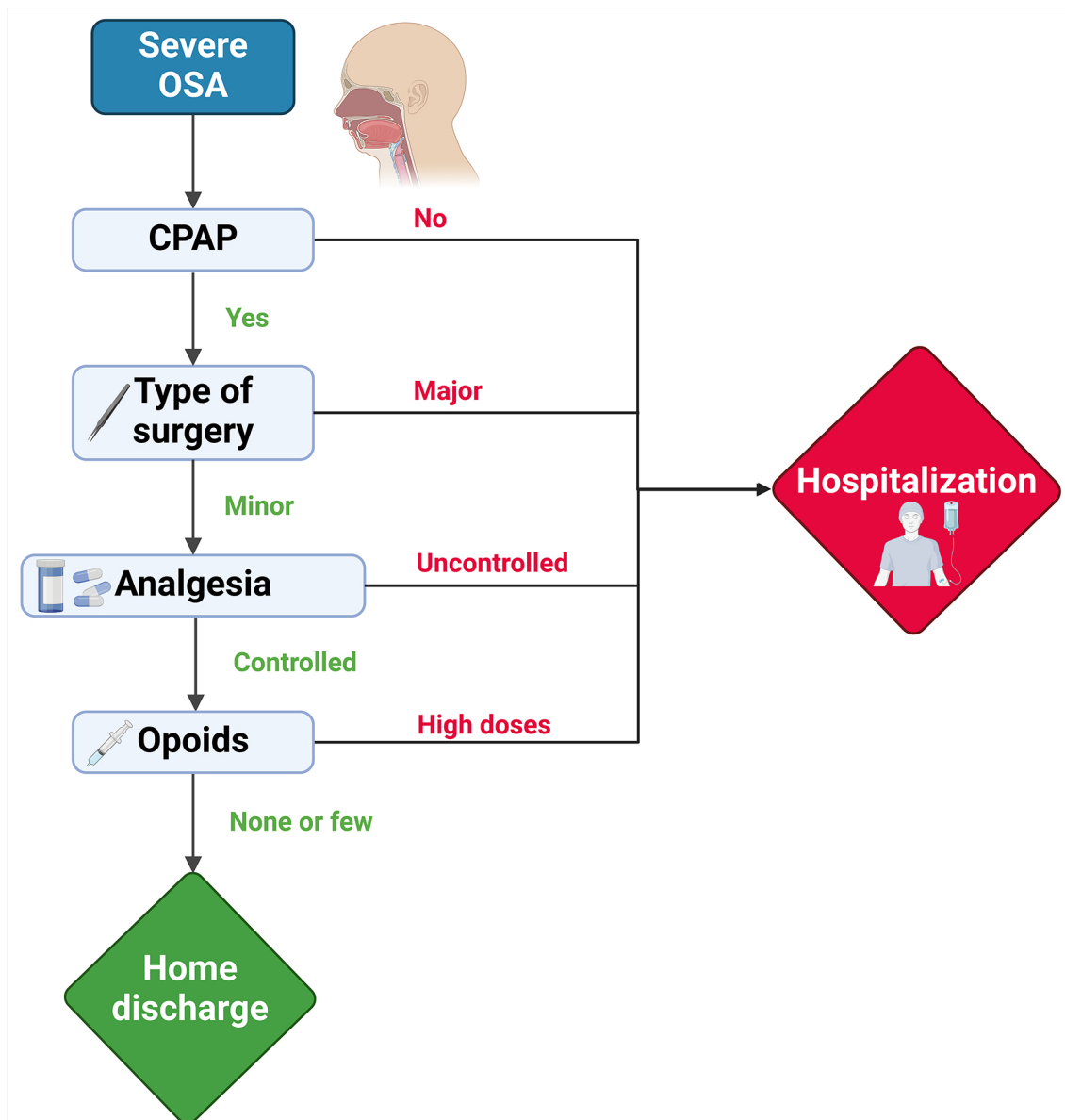


Fig. 4 — Decision algorithm regarding the eligibility of OSA patients for ambulatory surgery. Inspired by the guidelines of the ASA 7, the SASM 5, the SAMBA 6, and a consensus recommendations from M. Ravessloot 111. Severe obstructive sleep apnea (OSA) is diagnosed if the apnea/hypopnea index (AHI) is >30 and strongly suspected if the STOP-BANG score is >7 or if the DES-OSA score is >7 . At present, no evidence exists regarding the type of opioid or the opioid dose that is compatible with patient discharge following an outpatient procedure. The determination of the maximum effective dose compatible with patient discharge will be done on an individual basis, according to the clinician in charge appreciation.

Procedural sedation and general anesthesia

Sedation and general anesthesia (GA) necessitate adequate upper airway management. As described above, OSA patients are at high risk of difficult mask ventilation and early desaturation^{4,7,63,64}. This is frequently favored by overweight, a condition associated with a reduction in functional residual capacity. Optimal preoxygenation is therefore important, using means such as CPAP, non-invasive ventilation (NIV), and other oxygenation devices with high- or low-flow oxygen, with the patient placed in the ramp position, although no technique has been proven being superior to the other⁶⁵. These devices can also be useful during sedation without

instrumentation of the upper airway, to maintain oxygenation⁴⁷, while taking care of constantly monitoring capnography to detect obstruction or apnea. Frequent macroglossia and parapharyngeal fat deposits are responsible for upper airway narrowing, which impedes mask ventilation. Concomitantly, the risk of difficult intubation is higher⁶⁶, due to anatomical constraints such as narrow mandible, retrognathia or low implantation of the hyoid bone, leading to poor visualization of the glottic plane. Hence, the ASA recommendations on difficult intubation should be followed, with an early use of the video-laryngoscope⁶⁷. Conversely, in unscreened patients, the observation of a difficult intubation should prompt for investigations to

evidence OSA, insofar as 66% of unplanned difficult intubation cases suffer from OSA⁶⁸.

In addition to basic monitoring for sedation and general anesthesia, and procedure-specific ones, adequate titration of hypnotics and opioids is recommended, to reduce the risk of immediate postoperative adverse events. Electroencephalogram-derived indexes such as the Bispectral Index, and nociception-antinociception balance monitors are useful in this respect^{4,69}. Indeed, hypnotics and opioids affect the response of the pharyngeal dilator muscles and the ventilatory response to stimuli. Short acting drugs should therefore be preferred. Among the halogenated vapors, desflurane has the best profile, particularly in obese patients⁷⁰, but its benefits should be carefully weighed against its environmental impact⁷¹. The effect of propofol on the upper airway permeability is dose-dependent⁷², and, although rapidly eliminated, this medication tends to accumulate in obese patients. Its use should preferably occur through target-controlled infusion systems, to optimize titration. In OSA patients, the use of remifentanyl during an electroencephalogram-guided total intravenous anesthesia does not increase the length of stay in the post-anesthesia care unit (PACU), as well as the incidence of respiratory depression and postoperative complications^{73–75}. Similarly, total intravenous anesthesia with propofol, as compared to inhaled sevoflurane, is safe, reduces recovery times, and O₂ requirement^{76,77}. Benzodiazepines are not recommended in OSA patients, because all having a relatively long duration of action, increasing upper airway resistance to ventilation⁷⁸, and impeding the ventilatory response to hypoxia⁷⁹. Ketamine maintains the upper airway patency⁸⁰, and has minimal effects on the central ventilatory control. In addition to its bronchodilation properties⁸¹, this makes it a suitable molecule for anesthesia and sedation in OSA patients, as part of a multimodal anesthetic regimen. Alpha-2 agonists such as clonidine and dexmedetomidine either can serve as premedication, anesthetic adjuvants, or as sole sedative agents. When used as a premedication, clonidine reduces the need of propofol^{82–84} and opioids⁸⁴ during general anesthesia and does not increase the number of desaturation episodes postoperatively⁸⁴. Studies are contradictory concerning the effect of dexmedetomidine on ventilation. Observations of ventilatory depression and arterial CO₂ partial pressure increases⁸⁵ rub shoulders with observations of no effect on ventilation^{86,87}, in a spontaneously breathing patient. In the PACU, the intraoperative use of dexmedetomidine raises the risk of residual moderate to profound sedation, which can be problematic in OSA patients⁸⁸. Neuromuscular

blocking agents are necessary when tracheal intubation is need, and for some surgeries to ensure immobility and facilitate the work of surgeons. OSA patients are more vulnerable to their use, because of an increased risk of postoperative respiratory complications in case of residual muscle relaxation. It is therefore recommended to use antagonizable muscle relaxants, and rocuronium is best choice in this respect because being immediately and completely antagonizable with sugammadex. In the general population, the antagonization of steroid muscle relaxants with sugammadex is associated with less postoperative pulmonary complications as compared with antagonization with neostigmine⁸⁹. These findings are probably transposable to OSA patients. In any case, the continuous intraoperative monitoring of muscle relaxation is mandatory when muscle relaxants are used, and train of four ratio >90% should be targeted before tracheal extubation at the end of the procedure. Tracheal extubation should be performed in a semi-sitting fully awake patient responding to command.

Locoregional anesthesia

Whenever possible, a locoregional anesthesia technique should be preferred to procedural sedation or general anesthesia in OSA patients. Indeed, locoregional techniques have very few effects on ventilation, and allow getting rid of airway management problems^{90,91}. In addition to general anesthesia, an epidural analgesia technique without opioids can be used safely in OSA patients undergoing major abdominal or thoracic open surgery. Contrarily, caution should be paid to the use of opioids as part of the mixture used to perform a locoregional technique, because of a possible systemic resorption. Intrathecal analgesia with morphine in doses of less than 100 µg has not been shown to increase the risk of life-threatening postoperative complications in OSA patients⁹², but the risk of delayed respiratory depression following higher doses should be kept in mind⁹³.

Anti-nociception management

OSA patients are more sensitive to noxious stimulation, possibly because of a high background sympathetic tonus. Intermittent hypoxia and sleep disorganization is also responsible for an upregulation of cerebral µ receptors, hence promoting the central effects of opioids⁹⁴. Despite the current tendency for intraoperative opioid sparing, those molecules are often necessary to deal with moderately to severely invasive surgery. However, they depress the respiratory centers and reduce pharyngeal muscle tone in a dose-

dependent manner. Consequently, in OSA patients, multimodal anti-nociception⁶², opioid sparing, and use of short-acting molecules is particularly pertinent. As a function of surgery invasiveness, and in the absence of contraindications, a cocktail of anti-nociception/analgesic medications should already be administered during surgery, including non-steroid anti-inflammatory drugs, magnesium sulfate⁹⁵, lidocaine, corticosteroids, ketamine, and/or $\alpha 2$ -agonists. Locoregional anesthesia techniques are also part of the multimodal opioid-sparing approach^{90,91}. Noteworthy, local anesthesia of the upper airway is contraindicated in OSA patients, because of the risk of upper airway reflexes abolition.

Intraoperative fluid management

Intra-operative fluid-management should be rather restrictive in OSA patients, strictly targeting euvoemia and avoiding hypervolemia. Indeed, fluid overload can lead to oedema of the neck and pharynx, thus reducing upper airway patency, and increasing the risk of collapse events⁹⁶.

The special case of drug-induced sleep endoscopy

Drug-induced sleep endoscopy (DISE) consists in performing nasal endoscopy during monitored anesthesia care in the supine or lateral position. It permits to localize the place of pharyngeal narrowing, responsible for upper airway obstruction, snoring, and OSA. For this procedure, sedation should mimic physiological sleep as much as possible. Most of practitioners use a combination of midazolam at a starting dose of 0.05 mg.Kg-1 and a continuous target-controlled infusion of propofol⁹⁷. This type of sedation does not induce physiological sleep at all, and alternatives should be thought at, with agents like dexmedetomidine. However, the particularly long onset time of dexmedetomidine sedative effect and its unfavorable context-sensitive half-life render the use of this medication for DISE unpractical. Recently, the utility of remimazolam, a short acting benzodiazepine, for DISE has been investigated⁹⁸. It provides adequate conditions for the examination, with less frequent episodes of hypoxemia when compared to propofol. Its place in the management of OSA patients, for example in case of procedural sedation or as the principal hypnotic agent during anesthesia, has yet to be defined, given the current lack of data in this respect, but this medication appears to be promising.

Post-operative management of obstructive sleep apnea patients

The postoperative period is particularly at risk of complications in severe OSA patients, which can be

of respiratory, cardiovascular, or thromboembolic nature. These risks are high during the first 30 postoperative days after cardiac⁹⁹ and non-cardiac surgery^{100,101}. The serious and sometimes life-threatening respiratory events occur mainly during the first 72 postoperative hours, with 80% of them happening within 24 hours¹⁰². They are favored by a lack of prevention, notably regarding the use of sedatives and opioids altering sleep patterns and increasing the AHI, and by poor monitoring¹⁰². Between the 24th and 72d postoperative hour, serious respiratory events are related to the recovery of sleep REM phases, during which apneas/hypopneas are more frequent^{103,104}. The optimal postoperative management of severe OSA patients necessitates adequate monitoring, including electrocardiography, intermittent arterial blood pressure measurements, and peripheral oxygen saturation. The addition of CO₂ monitoring (capnography or transcutaneous CO₂ monitoring) and respiratory rate monitoring (through thoracic impedance measurements, for example) provides faster detection of respiratory dysfunction¹⁰⁵. There is a lack of literature to determine the optimum monitoring range, and length. The ASA recommends a continuous monitoring in the recovery room and on the ward using telemetry⁷. However, these recommendations are not easy to apply routinely on the ward, given the high cost of telemetry and high number of OSA patients. In addition, data demonstrating the effectiveness of those measures on outcome are lacking, despite the knowledge that serious adverse events such as death and/or brain damage occurring during the postoperative period are particularly linked to the absence of monitoring during the first 24 postoperative hours¹⁰⁶.

Others have proposed to calculate a score based on suspected or diagnosed OSA severity, ongoing treatment with CPAP, invasiveness of the surgery and chosen anesthesia technique, need for opioids, and presence of hypercapnia (Figure 5)¹⁵. Patients with a score ≥ 4 or < 4 without the possibility to use a CPAP must be monitored in the PACU for 2 to 4 additional hours. If no adverse events occur during this period, then patients are allowed to go to the ward. Otherwise, they stay in the PACU overnight. If the score is < 4 , and the patient is stable, even in patients with comorbidities, then he/she can be transferred to the ward after the usual postoperative assessment in the PACU. In case of destabilization, they follow the track of patients with a score ≥ 4 .

Other general protective measures can be undertaken during the postoperative period to increase patient safety. The semi-sitting position or lateral position should be favored, as it reduces

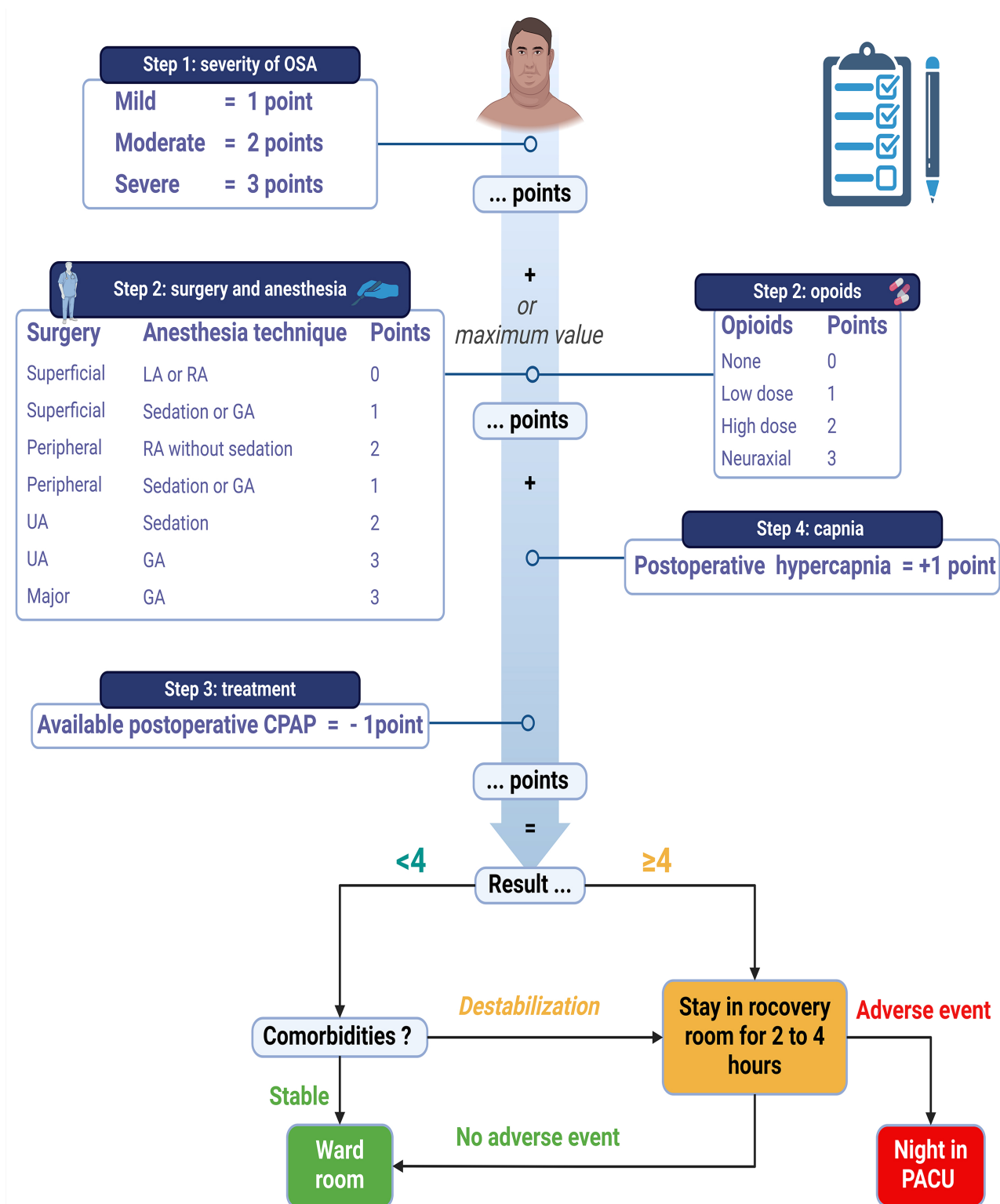


Fig. 5 — Postoperative obstructive sleep apnea patient management score. See text for details. Inspired by the ASA recommendations 7 and a review paper by Deflandre et al. 15. OSA = Obstructive Sleep Apnea-hypopnea. UA = Upper Airway. LA = Local Anesthesia. RA = Regional Anesthesia. GA = General Anesthesia. PACU = Post-Anesthesia Care Unit.

the AHI. Oxygen supplementation should be used under the same conditions as in the general population. Oxygen has the advantage of stabilizing the ventilatory response to hypoxia/hypercapnia in patients with a high loop gain²². It prevents desaturation without increasing the AHI, keeping in mind that hyperoxia sometimes leads to central apnea¹⁰⁹. As intraoperatively, opioid sparing and

multimodal analgesia should be the rule in OSA patients. In patients using CPAP at home, CPAP should be maintained postoperatively, with or without supplemental oxygen⁴⁵, although the compliance rate during the postoperative period is less than 50% because of surgical contraindications to CPAP use, inefficiency, presence of a nasogastric tube, intolerance, nausea, and upper airway

oedema. This may necessitate the adaptation of CPAP parameters¹¹⁰. Nevertheless, the use of postoperative CPAP seems to be associated with better outcomes by reducing the AHI, the number of desaturation episodes, and the need for O₂ than the use of high-flow oxygen devices⁶⁶. In high-risk OSA, high-flow oxygen does not reduce the incidence of hypoxia, hypercapnia or airway management maneuvers when compared to conventional oral or nasal low flow O₂^{67,68}. Hence, the environmental impact of using high-flow devices should be put in perspective with their expected benefits before deciding to use them. In patient with a severe upper airway obstructive profile, inspiratory efforts may be responsible for an acute pulmonary oedema on negative pressure. In these patients, the introduction of non-invasive ventilation should be considered. Finally, optimal postoperative nausea and vomiting prevention using, for example, intravenous dexamethasone should be introduced, and an eye should be kept on glycemia, given the insulin resistance associated with OSA⁶².

Conclusion

OSA is a complex and common upper airway respiratory disorder. This condition is under-diagnosed in the elective surgical population, yet its prevalence will considerably rise in the coming years. Patients with severe OSA are at increased risk of cardiorespiratory complications. Their perioperative management necessitates adequate preoperative screening, intra- and postoperative opioid sparing (including the use of locoregional techniques), and decision algorithm-oriented postoperative follow-up. An adequate locally defined care pathway is the key to ensure perioperative OSA patient safety.

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References

1. Benjafield A V, Ayas NT, Eastwood PR, et al. Estimation of the global prevalence and burden of obstructive sleep apnoea: a literature-based analysis. *Lancet Respir Med* 2019;7(8):687-698.
2. McNicholas WT, Bonsignore MR. Sleep apnoea as an independent risk factor for cardiovascular disease:

- current evidence, basic mechanisms and research priorities. *Eur Respir J* 2007;29(1):156-178.
3. Yacoub M, Youssef I, Salifu MO, McFarlane SI. Cardiovascular Disease Risk in Obstructive Sleep apnea: An Update. *J sleep Disord Ther* 2017;7(1).
 4. Memtsoudis SG, Cozowicz C, Nagappa M, et al. Society of Anesthesia and Sleep Medicine Guideline on Intraoperative Management of Adult Patients With Obstructive Sleep Apnea. *Anesth Analg* 2018;127(4):967-987.
 5. Chung F, Memtsoudis SG, Ramachandran SK, 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):452-473.
 6. 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):1060-1068.
 7. 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):268-286.
 8. Senaratna C V, Perret JL, Lodge CJ, et al. Prevalence of obstructive sleep apnea in the general population: A systematic review. *Sleep Med Rev* 2017;34:70-81.
 9. Vasu TS, Grewal R, Doghramji K. Obstructive sleep apnea syndrome and perioperative complications: a systematic review of the literature. *J Clin sleep Med JCSM Off Publ Am Acad Sleep Med* 2012;8(2):199-207.
 10. Reed K, Pengo MF, Steier J. Screening for sleep-disordered breathing in a bariatric population. *J Thorac Dis* 2016;8(2):268-275.
 11. Heinzer R, Vat S, Marques-Vidal P, et al. Prevalence of sleep-disordered breathing in the general population: the HypnoLaus study. *Lancet Respir Med* 2015;3(4):310-318.
 12. Lyons MM, Bhatt NY, Pack AI, Magalang UJ. Global burden of sleep-disordered breathing and its implications. *Respirology* 2020;25(7):690-702.
 13. Eckert DJ. Phenotypic approaches to obstructive sleep apnoea - New pathways for targeted therapy. *Sleep Med Rev* 2018;37:45-59.
 14. Destors M, Tamisier R, Galerneau LM, Lévy P, Pepin JL. [Pathophysiology of obstructive sleep apnea syndrome and its cardiometabolic consequences]. *Presse Med* 2017;46(4):395-403.
 15. Deflandre E, Joris J, Benhamou D. Rationalisation de la gestion périopératoire du syndrome d'apnées et d'hypopnées obstructives du sommeil (SAHOS). *Anesthésie & Réanimation* 2020;6(4):412-423.
 16. Cozowicz C, Memtsoudis SG. Perioperative Management of the Patient With Obstructive Sleep Apnea: A Narrative Review. *Anesth Analg* 2021;132(5):1231-1243.
 17. Deacon-Diaz N, Malhotra A. Inherent vs. Induced Loop Gain Abnormalities in Obstructive Sleep Apnea. *Front Neurol* 2018;9:896.
 18. Maieran AD, Bordea IR, Salagean T, et al. Polymorphism of the Serotonin Transporter Gene and the Peripheral 5-Hydroxytryptamine in Obstructive Sleep Apnea: What Do We Know and What are We Looking for? A Systematic Review of the Literature. *Nat Sci Sleep* 2021;13:125-139.
 19. Redline S, Tishler P V. The genetics of sleep apnea. *Sleep Med Rev* 2000;4(6):583-602.
 20. (UNFPA) UNPF. World Population Ageing 2019.; 2019. http://www.un.org/esa/population/publications/worldageing19502050/pdf/65executivesummaryspanish.pdf%0Ahttp://link.springer.com/chapter/10.1007/978-94-007-5204-7_6

21. Bonsignore MR, Saaresranta T, Riha RL. Sex differences in obstructive sleep apnoea. *Eur Respir Rev an Off J Eur Respir Soc* 2019;28(154).
22. Basner M, Müller U, Elmenhorst EM. Single and combined effects of air, road, and rail traffic noise on sleep and recuperation. *Sleep* 2011;34(1):11-23.
23. Altree TJ, Chung F, Chan MT V, Eckert DJ. Vulnerability to Postoperative Complications in Obstructive Sleep Apnea: Importance of Phenotypes. *Anesth Analg* 2021;132(5):1328-1337.
24. 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):179-191.
25. Chung F, Yegneswaran B, Liao P, et al. STOP questionnaire: a tool to screen patients for obstructive sleep apnea. *Anesthesiology* 2008;108(5):812-821.
26. Stadler DL, McEvoy RD, Sprecher KE, et al. Abdominal compression increases upper airway collapsibility during sleep in obese male obstructive sleep apnea patients. *Sleep* 2009;32(12):1579-1587.
27. Hnin K, Mukherjee S, Antic NA, et al. The impact of ethnicity on the prevalence and severity of obstructive sleep apnea. *Sleep Med Rev* 2018;41:78-86.
28. Sutherland K, Lee RWW, Cistulli PA. Obesity and craniofacial structure as risk factors for obstructive sleep apnoea: impact of ethnicity. *Respirology* 2012;17(2):213-222.
29. Joosten SA, O'Driscoll DM, Berger PJ, Hamilton GS. Supine position related obstructive sleep apnea in adults: pathogenesis and treatment. *Sleep Med Rev* 2014;18(1):7-17.
30. Bonsignore MR, Mazzuca E, Baiaomonte P, Bouckaert B, Verbeke W, Pevernagie DA. REM sleep obstructive sleep apnoea. *Eur Respir Rev an Off J Eur Respir Soc* 2024;33(171).
31. Sands SA, Terrill PI, Edwards BA, et al. Quantifying the Arousal Threshold Using Polysomnography in Obstructive Sleep Apnea. *Sleep* 2018;41(1).
32. Younes M. Role of respiratory control mechanisms in the pathogenesis of obstructive sleep disorders. *J Appl Physiol* 2008;105(5):1389-1405.
33. Loewen AHS, Ostrowski M, Laprairie J, Maturino F, Hanly PJ, Younes M. Response of genioglossus muscle to increasing chemical drive in sleeping obstructive apnea patients. *Sleep* 2011;34(8):1061-1073.
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.
35. Drager LF, Polotsky VY, O'Donnell CP, Cravo SL, Lorenzi-Filho G, Machado BH. Translational approaches to understanding metabolic dysfunction and cardiovascular consequences of obstructive sleep apnea. *Am J Physiol Heart Circ Physiol* 2015;309(7):H1101-11.
36. Ke X, Guo W, Peng H, et al. Association of aldosterone excess and apnea-hypopnea index in patients with resistant hypertension. *Sci Rep* 2017;7:45241.
37. Logan AG, Perlikowski SM, Mente A, et al. High prevalence of unrecognized sleep apnoea in drug-resistant hypertension. *J Hypertens* 2001;19(12):2271-2277.
38. Wang Y, Li CX, Lin YN, et al. The Role of Aldosterone in OSA and OSA-Related Hypertension. *Front Endocrinol (Lausanne)* 2021;12:801689.
39. Salman LA, Shulman R, Cohen JB. Obstructive Sleep Apnea, Hypertension, and Cardiovascular Risk: Epidemiology, Pathophysiology, and Management. *Curr Cardiol Rep* 2020;22(2):6.
40. Cambron L, Roelants F, Deflandre E, Raskin S, Poirrier R. [The sleep obstructive apnea and hypopnea syndromes]. *Rev Med Liege* 2004;59(1):19-28.
41. Savransky V, Nanayakkara A, Li J, et al. Chronic intermittent hypoxia induces atherosclerosis. *Am J Respir Crit Care Med* 2007;175(12):1290-1297.
42. Baguet JP, Hammer L, Lévy P, et al. The severity of oxygen desaturation is predictive of carotid wall thickening and plaque occurrence. *Chest* 2005;128(5):3407-3412.
43. Adir Y, Humbert M, Chaouat A. Sleep-related breathing disorders and pulmonary hypertension. *Eur Respir J* 2021;57(1).
44. Fernández-Bello I, Monzón Manzano E, García Río F, et al. Procoagulant State of Sleep Apnea Depends on Systemic Inflammation and Endothelial Damage. *Arch Bronconeumol* 2022;58(2):117-124.
45. 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. *Anesthesiology* 2009;110(4):869-877.
46. 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):707-718.
47. Szeto B, Vertosick EA, Ruiz K, et al. Outcomes and Safety Among Patients With Obstructive Sleep Apnea Undergoing Cancer Surgery Procedures in a Freestanding Ambulatory Surgical Facility. *Anesth Analg* 2019;129(2):360-368.
48. Rosero EB, Joshi GP. Outcomes of Sleep Apnea Surgery in Outpatient and Inpatient Settings. *Anesth Analg* 2021;132(5):1215-1222.
49. Temirbekov D, Güneş S, Yazıcı ZM, Sayın İ. The Ignored Parameter in the Diagnosis of Obstructive Sleep Apnea Syndrome: The Oxygen Desaturation Index. *Turkish Arch Otorhinolaryngol* 2018;56(1):1-6.
50. Chang JL, Goldberg AN, Alt JA, et al. International Consensus Statement on Obstructive Sleep Apnea. *Int Forum Allergy Rhinol* 2023;13(7):1061-1482.
51. Ramachandran SK, Kheterpal S, Consens F, et al. Derivation and validation of a simple perioperative sleep apnea prediction score. *Anesth Analg* 2010;110(4):1007-1015.
52. Netzer NC, Stoohs RA, Netzer CM, Clark K, Strohl KP. Using the Berlin Questionnaire to identify patients at risk for the sleep apnea syndrome. *Ann Intern Med* 1999;131(7):485-491.
53. Deflandre E, Degey S, Brichant JFF, et al. Pre-Operative Ability of Clinical Scores to Predict Obstructive Sleep Apnea (OSA) Severity in Susceptible Surgical Patients. *Obes Surg* 2017;27(3):716-729.
54. Bernhardt L, Brady EM, Freeman SC, et al. Diagnostic accuracy of screening questionnaires for obstructive sleep apnoea in adults in different clinical cohorts: a systematic review and meta-analysis. *Sleep Breath* 2022;26(3):1053-1078.
55. Deflandre E, Piette N, Bonhomme V, et al. Comparison of clinical scores in their ability to detect hypoxemic severe OSA patients. *PLoS One* 2018;13(5).
56. Gaspar LS, Santos-Carvalho A, Santos B, et al. Peripheral biomarkers to diagnose obstructive sleep apnea in adults: A systematic review and meta-analysis. *Sleep Med Rev* 2022;64:101659.
57. Hauquiert B, Drion E, Deflandre E. [The role of biomarkers in the detection of the OSA syndrome. A narrative review of the literature]. *Rev Mal Respir* 2021;38(5):455-465.
58. Nowak N, Engler A, Thiel S, et al. Validation of breath biomarkers for obstructive sleep apnea. *Sleep Med* 2021;85:75-86.
59. Finkel KJ, Searleman AC, Tymkew H, et al. Prevalence of undiagnosed obstructive sleep apnea among adult surgical patients in an academic medical center. *Sleep Med* 2009;10(7):753-758.

60. Sánchez-de-la-Torre M, Gracia-Lavedan E, Benitez ID, et al. Adherence to CPAP Treatment and the Risk of Recurrent Cardiovascular Events: A Meta-Analysis. *JAMA* 2023;330(13):1255-1265.
61. Litvin AY, Sukmarova ZN, Elfimova EM, et al. Effects of CPAP on "vascular" risk factors in patients with obstructive sleep apnea and arterial hypertension. *Vasc Health Risk Manag* 2013;9:229-235.
62. Joshi GP. Rational Multimodal Analgesia for Perioperative Pain Management. *Curr Pain Headache Rep* 2023;27(8):227-237.
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.
64. Kheterpal S, Martin L, Shanks AM, Tremper KK. Prediction and outcomes of impossible mask ventilation: a review of 50,000 anesthetics. *Anesthesiology* 2009;110(4):891-897.
65. Murphy C, Wong DT. Airway management and oxygenation in obese patients. *Can J Anaesth* 2013;60(9):929-945.
66. Kim JA, Lee JJ. Preoperative predictors of difficult intubation in patients with obstructive sleep apnea syndrome. *Can J Anaesth* 2006;53(4):393-397.
67. Apfelbaum JL, Hagberg CA, Connis RT, et al. 2022 American Society of Anesthesiologists Practice Guidelines for Management of the Difficult Airway. *Anesthesiology* 2022;136(1):31-81.
68. Chung F, Yegneswaran B, Herrera F, Shenderey A, Shapiro CM. Patients with difficult intubation may need referral to sleep clinics. *Anesth Analg* 2008;107(3):915-920.
69. Ibraheim O, Alshaer A, Mazen K, et al. Effect of bispectral index (BIS) monitoring on postoperative recovery and sevoflurane consumption among morbidly obese patients undergoing laparoscopic gastric banding. *Middle East J Anaesthesiol* 2008;19(4):819-830.
70. Liu FL, Cherng YG, Chen SY, et al. Postoperative recovery after anesthesia in morbidly obese patients: a systematic review and meta-analysis of randomized controlled trials. *Can J Anaesth* 2015;62(8):907-917.
71. Buhre W. BESARPP recommendations on responsible and sustainable use of inhaled anesthetics: No time TO WASTE. *Acta Anaesthesiol Belg* 2023;74(4):241.
72. Eastwood PR, Platt PR, Shepherd K, Maddison K, Hillman DR. Collapsibility of the upper airway at different concentrations of propofol anesthesia. *Anesthesiology* 2005;103(3):470-477.
73. Kim Y, Park H, Shin J, Choi JH, Park SW, Kang HY. Effect of remifentanyl during drug-induced sleep endoscopy in patients with obstructive sleep apnea. *Sleep Breath* 2018;22(4):919-923.
74. Doufas AG, Shafer SL, Rashid NHA, Kushida CA, Capasso R. Non-steady State Modeling of the Ventilatory Depressant Effect of Remifentanyl in Awake Patients Experiencing Moderate-to-severe Obstructive Sleep Apnea. *Anesthesiology* 2019;130(2):213-226.
75. Stewart M, Estephan L, Thaler A, et al. Reduced Recovery Times with Total Intravenous Anesthesia in Patients with Obstructive Sleep Apnea. *Laryngoscope* 2021;131(4):925-931.
76. Estephan LE, Sussman S, Stewart M, et al. Total Intravenous Anesthesia Versus Inhaled Sevoflurane in Obstructive Sleep Apnea Surgery: A Randomized Controlled Trial. *Laryngoscope* 2023;133(4):984-992.
77. Sagalow ES, Stewart M, Estephan L, et al. Assessing Postoperative Recovery With Volatile Gas Versus Total Intravenous Anesthesia in Patients With and Without Obstructive Sleep Apnea. *Ann Otol Rhinol Laryngol* 2023;132(6):667-673.
78. Montravers P, Dureuil B, Desmonts JM. Effects of i.v. midazolam on upper airway resistance. *Br J Anaesth* 1992;68(1):27-31.
79. Leiter JC, Knuth SL, Bartlett DJ. The effect of sleep deprivation on activity of the genioglossus muscle. *Am Rev Respir Dis* 1985;132(6):1242-1245.
80. Eikermann M, Garzon-Serrano J, Kwo J, Grosse-Sundrup M, Schmidt U, Bigatello L. Do Patients with Obstructive Sleep Apnea have an Increased Risk of Desaturation During Induction of Anesthesia for Weight Loss Surgery? *Open Respir Med J* 2010;4:58-62.
81. Miller AC, Jamin CT, Elamin EM. Continuous intravenous infusion of ketamine for maintenance sedation. *Minerva Anesthesiol* 2011;77(8):812-820.
82. Goyagi T, Tanaka M, Nishikawa T. Oral clonidine premedication reduces induction dose and prolongs awakening time from propofol-nitrous oxide anesthesia. *Can J Anaesth* 1999;46(9):894-896.
83. Imai Y, Mammoto T, Murakami K, et al. The effects of preanesthetic oral clonidine on total requirement of propofol for general anesthesia. *J Clin Anesth* 1998;10(8):660-665.
84. Pawlik MT, Hansen E, Waldhauser D, Selig C, Kuehnle TS. Clonidine premedication in patients with sleep apnea syndrome: a randomized, double-blind, placebo-controlled study. *Anesth Analg* 2005;101(5):1374-1380.
85. Belleville JP, Ward DS, Bloor BC, Maze M. Effects of intravenous dexmedetomidine in humans. I. Sedation, ventilation, and metabolic rate. *Anesthesiology* 1992;77(6):1125-1133.
86. Nelson LE, Lu J, Guo T, Saper CB, Franks NP, Maze M. The alpha2-adrenoceptor agonist dexmedetomidine converges on an endogenous sleep-promoting pathway to exert its sedative effects. *Anesthesiology* 2003;98(2):428-436.
87. Hsu YW, Cortinez LI, Robertson KM, et al. Dexmedetomidine pharmacodynamics: part I: crossover comparison of the respiratory effects of dexmedetomidine and remifentanyl in healthy volunteers. *Anesthesiology* 2004;101(5):1066-1076.
88. Kruthiventi SC, Hofer RE, Warner ME, Sprung J, Kellogg TA, Weingarten TN. Postoperative nausea and vomiting after bariatric surgery and dexmedetomidine anesthetic: a propensity-weighted analysis. *Surg Obes Relat Dis Off J Am Soc Bariatric Surg* 2020;16(4):545-553.
89. Kheterpal S, Vaughn MT, Dubovoy TZ, et al. Sugammadex versus Neostigmine for Reversal of Neuromuscular Blockade and Postoperative Pulmonary Complications (STRONGER): A Multicenter Matched Cohort Analysis. *Anesthesiology* 2020;132(6):1371-1381.
90. Memtsoudis SG, Stundner O, Rasul R, 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):274-281.
91. Cozowicz C, Stundner O, Memtsoudis SG. Regional anesthesia and pain management in patients with sleep apnea: can they improve outcomes? *Curr Opin Anaesthesiol* 2019;32(5):683-689.
92. Bai JW, Singh M, Short A, et al. Intrathecal Morphine and Pulmonary Complications after Arthroplasty in Patients with Obstructive Sleep Apnea: A Retrospective Cohort Study. *Anesthesiology* 2020;132(4):702-712.
93. Albrecht E, Bayon V, Hirotsu C, Al Ja'bari A, Heinzer R. Intrathecal morphine and sleep apnoea severity in patients undergoing hip arthroplasty: a randomised, controlled, triple-blinded trial. *Br J Anaesth* 2020;125(5):811-817.
94. Moss IR, Laferrière A. Central neuropeptide systems and respiratory control during development. *Respir Physiol Neurobiol* 2002;131(1-2):15-27.
95. Bakkali H, Mounir K, Bensghir M, et al. Intérêt de l'adjonction du sulfate de magnésium en rachianesthésie pour la réduction de la douleur postopératoire dans la

- chirurgie orthopédique des membres inférieurs. *Douleurs* 2014;4381(5):e7 YP-e8.
96. Lam T, Nagappa M, Wong J, Singh M, Wong D, Chung F. Continuous Pulse Oximetry and Capnography Monitoring for Postoperative Respiratory Depression and Adverse Events: A Systematic Review and Meta-analysis. *Anesth Analg* 2017;125(6):2019-2029.
 97. Memtsoudis SG, Cozowicz C, Bekeris J, et al. Anaesthetic care of patients undergoing primary hip and knee arthroplasty: consensus recommendations from the International Consensus on Anaesthesia-Related Outcomes after Surgery group (ICAROS) based on a systematic review and meta-analysis. *Br J Anaesth* 2019;123(3):269-287.
 98. Zhang J, Zhang Y, Fang X, et al. Comparison of Remimazolam and Propofol for Drug-Induced Sleep Endoscopy: A Randomized Clinical Trial. *Otolaryngol neck Surg Off J Am Acad Otolaryngol Neck Surg* 2023;169(5):1356-1365.
 99. Karimi N, Kelava M, Kothari P, Zimmerman NM, Gillinov AM, Duncan AE. Patients at High Risk for Obstructive Sleep Apnea Are at Increased Risk for Atrial Fibrillation After Cardiac Surgery: A Cohort Analysis. *Anesth Analg* 2018;126(6):2025-2031.
 100. Chan MT V, Wang CY, Seet E, et al. Association of Unrecognized Obstructive Sleep Apnea With Postoperative Cardiovascular Events in Patients Undergoing Major Noncardiac Surgery. *JAMA* 2019;321(18):1788-1798.
 101. Kaw R, Chung F, Pasupuleti V, Mehta J, Gay PC, Hernandez A V. Meta-analysis of the association between obstructive sleep apnoea and postoperative outcome. *Br J Anaesth* 2012;109(6):897-906.
 102. 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):885-899.
 103. Mokhlesi B, Punjabi NM. "REM-related" obstructive sleep apnea: an epiphenomenon or a clinically important entity? *Sleep* 2012;35(1):5-7.
 104. 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):287-298.
 105. Chung F, Wong J, Mestek ML, Niebel KH, Lichtenthal 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):541-551.
 106. Bolden N, Posner KL, Domino KB, et al. Postoperative Critical Events Associated With Obstructive Sleep Apnea: Results From the Society of Anesthesia and Sleep Medicine Obstructive Sleep Apnea Registry. *Anesth Analg* 2020;131(4):1032-1041.

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