



International Journal of Innovative Technologies in Social Science

e-ISSN: 2544-9435

Operating Publisher
SciFormat Publishing Inc.
ISNI: 0000 0005 1449 8214

2734 17 Avenue SW,
Calgary, Alberta, T3E0A7,
Canada
+15878858911
editorial-office@sciformat.ca

ARTICLE TITLE	MODERN DIAGNOSTIC AND THERAPEUTIC APPROACHES IN OBSTRUCTIVE SLEEP APNEA: FROM PHENOTYPING TO PRECISION MEDICINE
----------------------	---

DOI	https://doi.org/10.31435/ijitss.2(50).2026.5715
------------	---

RECEIVED	18 March 2026
-----------------	---------------

ACCEPTED	22 June 2026
-----------------	--------------

PUBLISHED	30 June 2026
------------------	--------------

LICENSE



The article is licensed under a **Creative Commons Attribution 4.0 International License**.

© The author(s) 2026.

This article is published as open access under the Creative Commons Attribution 4.0 International License (CC BY 4.0), allowing the author to retain copyright. The CC BY 4.0 License permits the content to be copied, adapted, displayed, distributed, republished, or reused for any purpose, including adaptation and commercial use, as long as proper attribution is provided.

MODERN DIAGNOSTIC AND THERAPEUTIC APPROACHES IN OBSTRUCTIVE SLEEP APNEA: FROM PHENOTYPING TO PRECISION MEDICINE

Julia Rydzek

Faculty of Medicine, Wroclaw Medical University, Wroclaw, Poland

Marta Zawadzka (Corresponding Author, Email: marta.zawadzka@student.umw.edu.pl)

Faculty of Medicine, Wroclaw Medical University, Wroclaw, Poland

ORCID ID: 0009-0007-3883-1327

Adrian Muzyka

Faculty of Medicine, Wroclaw Medical University, Wroclaw, Poland

Zuzanna Krupa

Faculty of Medicine, Wroclaw Medical University, Wroclaw, Poland

Joanna Wrona

Faculty of Medicine, Wroclaw Medical University, Wroclaw, Poland

Karolina Dorobisz

Department of Otolaryngology, Head and Neck Surgery, Wroclaw Medical University, Wroclaw, Poland

ABSTRACT

Objectives: The aim of this paper is to present current approaches to the diagnosis and management of obstructive sleep apnea (OSA), with particular emphasis on precision medicine, phenotyping, and the use of modern diagnostic tools. The study seeks to identify key challenges in optimizing treatment effectiveness and adherence, as well as to highlight the role of individualized therapeutic strategies.

Methods: A narrative review of the literature was conducted, focusing on contemporary diagnostic and therapeutic methods in OSA. Particular attention was given to phenotyping approaches, drug-induced sleep endoscopy (DISE), and the application of artificial intelligence (AI) in clinical decision making. Relevant studies were selected through targeted database searches and analyzed to identify trends and gaps in current practice.

Key findings: OSA is a heterogeneous disorder with significant variability in clinical presentation, pathophysiology, and treatment response. Traditional diagnostic and therapeutic approaches are often insufficient to address this complexity. Emerging strategies, including patient phenotyping, DISE, and AI-supported tools, enable more precise identification of disease mechanisms and support personalized treatment selection. These approaches show promise in improving diagnostic accuracy, treatment outcomes, and patient adherence.

Conclusions: Effective management of OSA requires a shift toward individualized, data-driven approaches. Advances in precision medicine and AI have the potential to significantly enhance diagnostic processes and therapeutic outcomes. Further research is needed to validate these methods and integrate them into routine clinical practice to improve quality of life in patients with OSA.

KEYWORDS

Obstructive Sleep Apnea, Precision Medicine, Phenotyping, Drug-Induced Sleep Endoscopy, Artificial Intelligence, Personalized Therapy

CITATION

Julia Rydzek, Marta Zawadzka, Adrian Muzyka, Zuzanna Krupa, Joanna Wrona, Karolina Dorobisz. (2026). Modern Diagnostic and Therapeutic Approaches in Obstructive Sleep Apnea: From Phenotyping to Precision Medicine. *International Journal of Innovative Technologies in Social Science*. 2(50). doi: 10.31435/ijitss.2(50).2026.5715

COPYRIGHT

© The author(s) 2026. This article is published as open access under the **Creative Commons Attribution 4.0 International License (CC BY 4.0)**, allowing the author to retain copyright. The CC BY 4.0 License permits the content to be copied, adapted, displayed, distributed, republished, or reused for any purpose, including adaptation and commercial use, as long as proper attribution is provided.

1. Introduction

Obstructive sleep apnea (OSA) is one of the most common sleep-related breathing disorders and represents an important clinical and public health challenge due to its broad systemic consequences. Traditionally, sleep-related apneas are classified into three types: obstructive apnea, characterized by persistent respiratory effort despite upper airway collapse; central apnea, resulting from the absence of respiratory drive; and mixed apnea, which combines both mechanisms (H. P. Chang et al., 2020; Jordan et al., 2014). Among these, OSA is the most prevalent form and is typically characterized by recurrent episodes of partial or complete upper airway obstruction during sleep, leading to intermittent hypoxia, sleep fragmentation, and fluctuations in intrathoracic pressure.

Although OSA has long been considered a single clinical entity, growing evidence indicates that it represents a highly heterogeneous disorder involving multiple interacting pathophysiological mechanisms. The classical paradigm attributes OSA primarily to anatomical narrowing and collapsibility of the upper airway during sleep. However, contemporary research demonstrates that non-anatomical factors also play a crucial role in many patients. These include instability of ventilatory control (high loop gain), reduced neuromuscular responsiveness of the upper airway dilator muscles, and a low arousal threshold. The relative contribution of these mechanisms varies substantially between individuals, resulting in considerable diversity in disease presentation, severity, and response to treatment.

This heterogeneity partly explains the limitations of traditional diagnostic and therapeutic approaches. Standard management strategies, most notably continuous positive airway pressure (CPAP), are highly effective in reducing respiratory events but do not adequately address the underlying pathophysiological variability of the disorder. Consequently, many patients experience suboptimal adherence or incomplete symptom control. Similarly, anatomical interventions such as upper airway surgery or oral appliance therapy may be effective in selected individuals but show variable outcomes when applied without careful patient selection.

In recent years, increasing attention has been directed toward the concept of OSA phenotyping, which aims to identify distinct clinical, anatomical, and physiological subtypes of the disease. This approach aligns with the broader principles of precision medicine, in which diagnostic strategies and therapeutic interventions are tailored to the specific characteristics of individual patients. Advances in sleep medicine including improved physiological measurements, imaging techniques, and emerging digital health technologies are creating new opportunities to better characterize OSA and personalize its management.

This review aims to critically analyze modern diagnostic and therapeutic approaches in OSA, focusing on how phenotyping and emerging technologies may enable more personalized management.

2. Methodology

This study constitutes a narrative review of the literature based on a structured search of scientific publications. The databases PubMed, Embase, and Scopus were systematically searched using the following keywords: “obstructive sleep apnea,” “OSA,” “polysomnography,” “continuous positive airway pressure,” “CPAP,” “BiPAP,” “mandibular advancement device,” “drug-induced sleep endoscopy,” “hypoglossal nerve stimulation,” “sleep surgery,” “artificial intelligence,” and “machine learning.” These terms were combined using the Boolean operators AND and OR to ensure a comprehensive and inclusive retrieval of relevant studies.

The literature selection process was descriptive rather than systematic; therefore, the PRISMA framework was not applied. Titles, abstracts, and full-text articles were reviewed, and studies most relevant to the objective of this review were included. Particular emphasis was placed on publications addressing the epidemiology, pathophysiology, clinical presentation, diagnostic methods, and both non-invasive and surgical treatment strategies for obstructive sleep apnea. Special attention was also given to emerging technologies, including artificial intelligence and machine learning, in the diagnosis and management of OSA.

A total of 139 publications were included, comprising original research articles, systematic reviews, meta-analyses, clinical guidelines, and narrative reviews. Only English-language articles published between 1999 and 2025 were considered to ensure both historical perspective and contemporary relevance. The collected data were analyzed narratively and synthesized to present current trends in the diagnosis and treatment of obstructive sleep apnea, as well as advancements in personalized and technology-assisted therapeutic approaches.

3. Diagnostics

The physical examination of patients with OSA includes parameters such as age, body mass index (BMI), neck circumference, assessment of craniofacial structures, and examination of the upper airway (the nose, oral cavity, and its pharyngeal portion). Taken together, these assessments may provide a more accurate estimation of disease risk than the evaluation of individual parameters alone (J. L. Chang et al., 2023).

A thorough nasal examination is essential, including the assessment of both external nasal structures and the nasal cavity using endoscopy. Treatment of nasal obstruction associated with OSA may improve both sleep quality and tolerance of continuous positive airway pressure (CPAP) therapy (Brander et al., 1999).

In patients with OSA, an enlarged uvula and collapse of the lateral pharyngeal walls may be observed; therefore, examination of the oral cavity is also of great importance (Ingman et al., 2004). The assessment of tonsillar size is also of significant importance, as tonsil size may correlate with the severity of OSA (Jara & Weaver, 2018).

There are numerous clinical tools designed to identify patients at high risk of OSA. The most commonly used include the Sleep Apnea Clinical Score, the Berlin Questionnaire, the OSA50 questionnaire, the STOP-Bang questionnaire, the elbow sign questionnaire, and the American Society of Anesthesiologists checklist. The Epworth Sleepiness Scale (ESS) is a useful instrument for assessing subjective daytime sleepiness and response to treatment (Laratta et al., 2017). ESS consists of eight questions addressing everyday situations, such as reading, watching television, sitting in a public place, being a passenger in a car, resting in the afternoon, talking with someone, and standing in traffic while driving. Each situation is scored on a scale from 0 to 3, where 0 indicates no sleepiness and 3 indicates a very high level of sleepiness. The total score ranges from 0 to 24, with higher scores indicating a greater propensity to fall asleep (Gonçalves et al., 2023).

The STOP-Bang questionnaire is a screening tool particularly well suited for surgical and obese patients. It can be easily implemented in the primary care setting (Semelka et al., 2016). The questionnaire consists of eight items addressing age, body mass index, male sex, neck circumference, snoring, fatigue, treatment for hypertension, and witnessed apneas, to which the respondent answers “yes” or “no.” It was designed to be a concise and easy-to-use screening instrument for OSA. The questionnaire also allows patients to be stratified into OSA risk categories based on the total score, with the maximum possible score being 8 (Chung et al., 2016).

The NoSAS score assesses five elements: neck circumference, obesity, snoring, age, and sex. Each component is assigned a specific number of points: 4 points for a neck circumference greater than 40 cm; 3 points for a BMI between 25 and <30 kg/m², or 5 points for a BMI of ≥30 kg/m²; 2 points for snoring; 4 points for age over 55 years; and 2 points for male sex. A total score of ≥8 indicates a high risk of OSA (Georgakopoulou et al., 2023).

The most reliable diagnostic test for OSA is overnight laboratory polysomnography, which measures the apnea–hypopnea index (AHI), defined as the number of apneas and hypopneas per hour of sleep. The examination involves simultaneous monitoring of sleep using electroencephalography (EEG), electrooculography, chin electromyography, and respiratory parameters, including respiratory effort, airflow, limb movements, and body position, taking into account the impact of position on OSA severity. Polysomnography remains the diagnostic gold standard for OSA; however, it is costly and time-consuming. Increasing attention is being given to home-based diagnosis and treatment. Randomized studies have shown that, in certain patient groups, home testing and management can be as effective as laboratory-based diagnostics, although these studies excluded patients with significant comorbidities, such as pulmonary disease or heart failure (Jordan et al., 2014).

Home sleep apnea tests serve as an alternative to laboratory polysomnography. Older devices record at least three data channels, typically including airflow, snoring, body position, heart rate, and oxygen saturation; however, they do not monitor sleep itself, which can lead to an underestimation of AHI (Laratta et al., 2017).

Newer CPAP devices also feature automatic titration and can record sleep-related variables, including AHI (Medical Advisory Secretariat, 2006).

Home assessment is sometimes used in screening for OSA. Home tests are considerably less expensive than laboratory studies and more convenient for patients. They can be particularly useful for OSA patients with significantly reduced oxygen saturation, as such impairments can be more easily documented using a smaller set of available parameters (Victor, 1999).

Overnight polysomnography also represents the gold standard for diagnosing and assessing the severity of OSA in children. According to the American Academy of Sleep Medicine (AASM) guidelines, the study involves comprehensive monitoring of multiple physiological parameters, including EEG, electrocardiography (ECG), oxygen saturation, end-tidal carbon dioxide (PETCO₂), body position and movements, sleep architecture, and the occurrence of obstructive, mixed, and central apneas. The diagnosis of pediatric OSA requires the presence of both clinical symptoms of sleep-disordered breathing (such as snoring, paradoxical respiratory movements, or daytime sleepiness) and abnormal polysomnographic findings (Bitners & Arens, 2020).

An increasing number of studies highlight the potential of AI as a tool for more accessible and efficient diagnosis of OSA. A literature review encompassing 344 publications on the use of AI in adult patients demonstrated that the most common applications included binary classification of patients (OSA-positive vs. OSA-negative), detection of respiratory events, assessment of disease severity, and estimation of AHI. The findings emphasize the growing role of machine learning and deep learning algorithms in sleep apnea diagnostics, suggesting that, in the coming years, they may serve as a valuable complement to traditional methods—particularly for population-level screening and home-based monitoring—while further clinical validation remains necessary (Kara et al., 2025).

4. Conservative treatment

Table 1. Treatment Methods for Obstructive Sleep Apnea (OSA)

Treatment Method	Mechanism of Action	Effectiveness / Benefits	Limitations / Adverse Effects	Preferred Patient Group	Selected Sources
CPAP (Continuous Positive Airway Pressure)	Continuous positive pressure keeps the upper airway open	Reduces apnea/hypoventilation, improves sleep quality and daytime alertness, lowers cardiovascular risk, cognitive benefits	Low tolerance, mask discomfort, mucosal dryness, claustrophobia	Moderate/severe OSA; first-line therapy	(Jiang et al., 2021; Rahman et al., 2024; Sulina et al., 2025)
autoCPAP (APAP) – Auto-adjusting CPAP	Automatic pressure adjustment based on obstruction	Similar effectiveness to CPAP; lower average pressures; better tolerance	Not recommended in heart failure, central apneas, or large mask leaks	Patients intolerant to fixed pressure or requiring variable pressure	(Benke et al., 2021; Ip et al., 2012; Rahman et al., 2024; Xu et al., 2012)
BiPAP (Bilevel Positive Airway Pressure)	Separate inhalation (IPAP) and exhalation (EPAP) pressures improve ventilation	Improves ventilation, reduces respiratory effort; useful in hypoventilation or CPAP intolerance	Higher cost; no superiority over CPAP as first-line therapy	Hypoventilation syndromes, COPD, CPAP intolerance	(Huang et al., 2025; Mansukhani et al., 2014; Palot et al., 2023; Witmer & Sullivan, 2025)
MAD – Mandibular Advancement Devices	Mandibular advancement enlarges the airway, reducing pharyngeal collapse	AHI reduction 50–72%; improved saturation, sleep quality, daytime alertness; good tolerance	Dental discomfort, TMJ issues, occlusal changes	Mild–moderate OSA; alternative for CPAP-intolerant patients	(Lo Giudice et al., 2024; Manetta et al., 2022; Nanda et al., 2025; Yu et al., 2023)
Pharmacological treatment (Modafinil, Solriamfetol)	Modulation of neurotransmitters: modafinil–dopamine; solriamfetol–dopamine/noradrenaline	Effective reduction of daytime sleepiness; solriamfetol more effective	Headache, nausea, decreased appetite, anxiety	Persistent sleepiness despite CPAP therapy	(Neshat et al., 2024; Ronnebaum et al., 2021; Schweitzer et al., 2021)
Lifestyle modification (weight loss, activity, behavioral therapy, positional therapy)	Reduction of risk factors (obesity, supine sleep), improved metabolic control	AHI reduction; improved quality of life; 5–10% weight loss significantly reduces OSA severity	Requires adherence; effectiveness depends on patient engagement	Overweight/obese patients; positional OSA; adjunct to CPAP/MAD	(Carneiro-Barrera et al., 2022; Igelström et al., 2016; Omobomi & Quan, 2018)

The gold standard of treatment is CPAP, which maintains upper airway patency through a constant flow of air, effectively reducing the number of episodes of apnea and hypoventilation, improving sleep quality, reducing daytime sleepiness and the risk of cardiovascular complications such as hypertension, arrhythmias and atherosclerosis (Jiang et al., 2021; Rahman et al., 2024; Sulina et al., 2025).

However, the effectiveness of CPAP therapy is limited by low tolerance and adherence – up to half of patients do not use the device regularly due to mask discomfort, dry mucous membranes, claustrophobia or lack of support from their partner (Rahman et al., 2024; Shaukat et al., 2022).

An alternative to classic CPAP is autoCPAP, which automatically adjusts the pressure to the patient's current needs based on detected episodes of obstruction. Studies show that autoCPAP is as effective as CPAP in reducing the number of apneas and improving sleep quality, while allowing for lower average pressures, which translates into better tolerance and slightly higher adherence and patient preference (Benke et al., 2021; Rahman et al., 2024; Xu et al., 2012). It is worth noting that autoCPAP is not recommended for patients with heart failure, a predominance of central apnea or significant mask leaks (Benke et al., 2021; Ip et al., 2012).

BiPAP (bilevel positive airway pressure) allows independent setting of higher inspiratory pressure (IPAP) and lower expiratory pressure (EPAP), which facilitates breathing, especially in people who cannot tolerate high CPAP pressures or who suffer from hypoventilation, e.g. in obesity-hypoventilation syndrome or chronic obstructive pulmonary disease (Huang et al., 2025; Mansukhani et al., 2014; Palot et al., 2023). BiPAP allows for better ventilation and breathing comfort and also reduces breathing effort during exhalation. The limitations of BiPAP are its higher cost and lack of advantage over CPAP as the first-choice therapy for most patients with OSA (Palot et al., 2023; Witmer & Sullivan, 2025; Zou et al., 2019).

Intraoral MAD (mandibular advancement devices) orthoses are an effective, non-invasive alternative to CPAP in the treatment of OSA, especially in patients with mild to moderate forms of the disease and in those who cannot tolerate CPAP therapy. The mechanism of action of MADs involves moving the lower jaw forward during sleep, which shifts the tongue and soft tissues of the throat, increasing the airway opening and reducing its susceptibility to collapse. The result is a reduction in the number of apnea episodes and improved oxygen saturation (Lo Giudice et al., 2024; Manetta et al., 2022; Nanda et al., 2025).

The choice of the appropriate type of orthosis (monoblock, biblock, custom-made or prefabricated devices) should be tailored to the patient's anatomical conditions and preferences, with custom-made and adjustable orthoses demonstrating higher effectiveness and comfort of use than thermoplastic, ready-to-use ones (Guichaoua et al., 2024; Lo Giudice et al., 2024; Manetta et al., 2022; Venema et al., 2021).

MADs are also effective in some patients with severe OSA who cannot tolerate CPAP, although complete resolution of symptoms is less likely than in milder forms (Leibovitz et al., 2025; Nanda et al., 2025). The effectiveness of the therapy depends on individual anatomical features, the degree of mandibular protrusion, and the regularity of use of the device (Camañes-Gonzalvo et al., 2022; Ma et al., 2020).

MADs are generally well tolerated, and adverse effects (tooth pain, bite changes, temporomandibular joint discomfort) are rare and mild (Guichaoua et al., 2024; Manetta et al., 2022; On et al., 2024; Yu et al., 2023).

Modafinil, a dopamine reuptake inhibitor, and solriamfetol, a dopamine and noradrenaline reuptake inhibitor, are drugs with proven efficacy in reducing daytime sleepiness in patients with OSA, both in short-term and long-term studies.

The effects of both drugs are visible after just a few weeks of use and persist throughout the entire treatment period. The most common side effects are headaches, nausea, loss of appetite and anxiety, most of which are mild or moderate in severity (Schweitzer et al., 2019, 2021; Winter et al., 2025).

In clinical practice, solriamfetol is currently preferred as the first-line treatment for excessive sleepiness in adults with OSA, especially when other drugs are ineffective or poorly tolerated, with modafinil remaining an alternative or adjunctive treatment (Abad, 2021; Javaheri & Javaheri, 2020; Lal et al., 2021).

The choice of medication should be tailored to the individual needs of the patient, taking into account the profile of adverse effects and concomitant diseases, especially cardiac diseases (Pépin et al., 2024).

OSA is a condition in which lifestyle modifications play a key role in both prevention and treatment. The most important element is weight reduction, as overweight and obesity are the main reversible risk factors for OSA. Moderate weight loss (5–10%) can significantly reduce the apnea index and improve sleep parameters, and in some cases lead to remission of the disease (Carneiro-Barrera et al., 2022; Georgoulis et al., 2021; St-Onge & Tasali, 2021).

Positioning, i.e. avoiding sleeping on your back, is an effective method, especially in patients with so-called positional OSA, where symptoms worsen when lying on your back.

Behavioural therapy, which includes education, psychological support and individual strategies for changing habits, helps maintain weight loss results and improves compliance with recommendations regarding physical activity and diet.

A summary of the most important forms of conservative OSA therapy is presented in *Table 1. Methods of conservative treatment of Obstructive Sleep Apnea (OSA)*.

5. Surgical treatment

Table 2. Surgical and Modern Treatment Methods for Obstructive Sleep Apnea (OSA)

Procedure Group	Mechanism of Action	Effectiveness / Findings	Limitations / Risks	Preferred Patients / Indications	Selected Sources
Septoplasty + turbinateplasty	Improves nasal patency, reduces upper airway resistance	Significant AHI reduction; improved PSG parameters; reduced daytime sleepiness	Limited AHI improvement in some patients; may require multilevel surgery	Patients with nasal obstruction; moderate OSA; CPAP intolerance	(Abd El-Aziz et al., 2018; Manjunatha et al., 2024; Moxness & Nordgård, 2014; C. Y. Park et al., 2014)
UPPP ± tonsillectomy	Widening of the oropharyngeal airway; reduction of palatal collapse	AHI reduction 35–95%; improved sleepiness and quality of life; tonsillectomy effective with tonsillar hypertrophy	Effectiveness anatomy-dependent; postoperative pain	Patients with palatal obstruction, enlarged tonsils; CPAP intolerance	(Baradaranfar et al., 2015; Stuck et al., 2018; Tschopp & Tschopp, 2019; Ulrich Sommer et al., 2016)
Radiofrequency techniques	Minimally invasive ablation of obstructive tissues	Improves OSA symptoms and snoring; less pain and quicker recovery than UPPP	Lower effectiveness in severe OSA; may require repeat procedures	Mild–moderate OSA; preference for minimally invasive treatment	(Amali et al., 2017; Tschopp et al., 2025)
TORS – transoral robotic surgery	Precise resection of tongue base and laryngeal tissues, enlarging the airway	AHI reduction ~24–25/h; ESS improvement 7–8 points; success rate 35–76%	Higher complication risk than RF (pain, 4–5% bleeding); requires specialized center	Tongue-base obstruction; multilevel OSA	(Baptista et al., 2022; Justin et al., 2016; Lechien et al., 2021)
Glossopexy / tongue-base reduction	Fixation or volume reduction of the tongue	Reduces tongue-level obstruction; improved AHI in multilevel treatment	Rarely used as standalone procedure	Tongue obstruction; typically combined with other techniques	(Baptista et al., 2022; Tsou et al., 2021)
DISE – drug-induced sleep endoscopy	Dynamic assessment of airway collapse during sleep	Improves surgical success prediction (51% → 86%)	Subjective; requires experience; needs further standardization	Patients qualifying for surgery, suspected multilevel obstruction	(Huntley et al., 2017; Meraj et al., 2017; Viana et al., 2022)
HGNS – hypoglossal nerve stimulation	Stimulation advances the tongue and opens the airway	AHI reduction 15–20/h; improved saturation, sleep quality, adherence	Requires implantation; possible mild discomfort or numbness	Moderate–severe OSA; CPAP intolerance; DISE-confirmed anatomy	(Alrubasy et al., 2024; Kent et al., 2019; Mashaqi et al., 2021)
Qualification scales (Friedman, NOHL, VOTE)	Friedman: anatomical exam; NOHL/VOTE: dynamic DISE evaluation	Predict surgical outcomes and tailor procedures	Experience-dependent; lack of full standardization	Patients qualifying for OSA surgery	(Cao et al., 2023; da Cunha Viana et al., 2017; Lin et al., 2020)

Multicentre studies have shown that combining septoplasty with reduction of the inferior turbinates (turbinoplasty) results in a significant reduction in AHI and an improvement in subjective sleep quality, compared to septoplasty alone (Abd El-Aziz et al., 2018; Moxness & Nordgård, 2014). Indicators such as the ESS and polysomnographic parameters (e.g. AHI, arousal index, oxygen saturation) improve after treatment (Avatef Fazeli et al., 2022; C. Y. Park et al., 2014; Takahashi et al., 2013).

Corrective nose procedures lead to increased airflow through the nose, which translates into reduced resistance in the upper airways and a reduction in the number of apnea episodes (Manjunatha et al., 2024; C. Y. Park et al., 2014; Takahashi et al., 2013). However, not all patients show a significant improvement in AHI – some of them require further interventions at other levels of the airways (Manjunatha et al., 2024; Newsome, 2023; C. Y. Park et al., 2014).

The greatest effectiveness of treatment is observed in patients with a clear anatomical obstruction in the nose (deviated septum, hypertrophy of the turbinates) and moderate OSA (Abd El-Aziz et al., 2018; C. Y. Park et al., 2014). These treatments are particularly recommended for patients who cannot tolerate CPAP therapy or who have anatomical obstacles preventing its effective use (M. K. Lee et al., 2022; Lv et al., 2023).

Surgical procedures in the throat area, such as uvulopalatopharyngoplasty (UPPP), tonsillectomy and radiofrequency techniques, are an important alternative for patients with OSA, especially when conservative treatment (e.g. CPAP) is ineffective or intolerable. The most commonly used surgery is UPPP, often combined with the removal of the palatine tonsils, which allows for widening of the throat and reduction in the number of apnea episodes (Stuck et al., 2018; Tschopp et al., 2024; Ulrich Sommer et al., 2016). UPPP with tonsillectomy leads to a significant improvement in AHI, a reduction in daytime sleepiness and a reduction in snoring (Baradaranfar et al., 2015; Stuck et al., 2018; Ulrich Sommer et al., 2016). Tonsillectomy as a standalone procedure in adults with tonsillar hypertrophy may be as effective as UPPP, while being less invasive (Sundman et al., 2022; Tschopp & Tschopp, 2019). The size of the tonsils is one of the most important predictors of surgical success – the larger the tonsils, the greater the chance of a significant improvement in AHI (Tschopp et al., 2023, 2024).

Radiofrequency techniques, both as standalone treatments and in combination with UPPP, show similar effectiveness in alleviating OSA symptoms, while causing less post-operative pain and enabling a faster recovery (Amali et al., 2017; Tschopp et al., 2025). These treatments are particularly recommended for patients who cannot tolerate CPAP or who have anatomical obstructions in the throat (Stuck et al., 2018; Ulrich Sommer et al., 2016). One of the modern methods is transoral robotic surgery (TORS) using the da Vinci system, which enables precise resection of the base of the tongue and, if necessary, procedures on laryngeal structures such as the epiglottis. TORS allows for effective enlargement of the throat lumen and reduction in the number of apnea episodes, which has been confirmed by numerous studies – the average reduction in the AHI index is approximately 24–25 events per hour, and the improvement in the ESS reaches 7–8 points (Justin et al., 2016; Lechien et al., 2021). This procedure is particularly recommended for patients with documented obstruction at the base of the tongue, often as part of multi-level surgery also involving the palate and nose (Baptista et al., 2022; Tsou et al., 2021; Vicini et al., 2014).

Glossopexy, or surgical immobilisation of the tongue, is less commonly used as a standalone procedure, but may be part of a complex surgical procedure, especially in patients with dominant obstruction at the level of the tongue.

A key tool in planning surgical procedures for the treatment of OSA, which involve the soft palate, tonsils, base of the tongue or epiglottis, has become endoscopy during drug-induced sleep (DISE), which allows for dynamic assessment of the sites and mechanisms of obstruction in conditions similar to natural sleep (Viana et al., 2022; Vroegop et al., 2020).

DISE enables precise identification of the levels and types of airway collapse, often revealing multi-level obstructions that may not be visible in a conscious laryngological examination (Meraj et al., 2017; Viana et al., 2022; Vroegop et al., 2020). Studies have shown that up to 60–65% of adult patients with OSA have obstruction at more than one level, and this frequency increases with BMI (Wang et al., 2024). In children, DISE allows for the detection of multilevel obstruction in approximately 60% of patients, leading to a change in the original surgical treatment plan in as many as 45% of them, enabling a more personalised and effective approach (Boudewyns et al., 2014; Kirkham et al., 2020; Wang et al., 2024). Although DISE is widely used and considered safe and well tolerated, the results of studies on its impact on long-term treatment outcomes are inconclusive. Nevertheless, DISE is currently considered an indispensable tool in planning multilevel

procedures, especially in patients with atypical anatomy or ineffective conservative treatment (Meraj et al., 2017; Viana et al., 2022; Vroegop et al., 2020).

In recent years, modern methods of treating OSA have emerged. One of the most promising techniques is hypoglossal nerve stimulation (HGNS), known under the trade name Inspire®. This system involves the surgical implantation of a stimulator that activates the hypoglossal nerve during inhalation, causing the tongue to protrude and open the upper airways. The effectiveness of this method has been confirmed by numerous studies, which have shown a significant reduction in the AHI (by an average of 15–20 episodes per hour) in both the short and long term, improved oxygen saturation, reduced daytime sleepiness and improved quality of life (Alrubasy et al., 2024; Kent et al., 2019; Mashaqi et al., 2021). Indications for surgery include moderate to severe OSA, CPAP intolerance, and appropriate anatomical structure confirmed by DISE examination (Asarkar et al., 2024; Hassan & Kaplish, 2021; Yamauchi et al., 2020).

It is worth noting that all these methods require careful patient selection, and their effectiveness depends on individual anatomical characteristics and the stage of the disease (Alrubasy et al., 2024; Kent et al., 2019; Mashaqi et al., 2021). Modern methods such as hypoglossal nerve stimulation, TORS and implants expand the treatment options for OSA, offering effective and well-tolerated alternatives for patients who do not benefit from traditional therapies (Alrubasy et al., 2024; Kent et al., 2019; Kezirian et al., 2014; Yamauchi et al., 2020).

The Friedman, NOHL and VOTE scales are widely used to assess the effectiveness of OSA treatment, allowing for precise patient classification and prediction of surgical treatment outcomes. The Friedman scale is based on the assessment of tongue position, tonsil size and BMI. It is a simple tool for the initial classification of patients and predicting the effectiveness of procedures such as uvulopalatopharyngoplasty (UPPP). A lower Friedman score (I) is associated with a higher success rate after UPPP, while higher scores (II and III) indicate a greater risk of failure (Berg et al., 2020; Cao et al., 2023). However, this scale is limited to assessment in the awake state and does not always reflect the actual sites of obstruction during sleep (Friedman et al., 2017; Zhao et al., 2020).

The NOHL (Nose, Oropharynx, Hypopharynx, Larynx) and VOTE (Velum, Oropharynx, Tongue base, Epiglottis) scales are used during DISE. They allow for dynamic assessment of the locations and degree of collapse of the upper airways. The VOTE scale enables detailed analysis of obstruction patterns (lateral, anteroposterior, concentric) and the degree of narrowing in individual segments of the throat, which is important for selecting the optimal surgical strategy (Cao et al., 2023; Lin et al., 2020; Zhao et al., 2020). The NOHL scale, although less detailed in terms of throat structures, also allows for assessment of the nasal cavity and is useful in planning multi-level procedures (da Cunha Viana et al., 2017; Pérez-Martín et al., 2022; Yang et al., 2021). DISE using VOTE and NOHL allows for better tailoring of the procedure to the individual needs of the patient, which translates into a higher surgical success rate (Cao et al., 2023; da Cunha Viana et al., 2017; Lin et al., 2020).

A summary of surgical and modern methods of OSA treatment is presented in *Table 2. Surgical and modern methods of OSA treatment*.

6. New directions and technologies

AI and ML are experiencing rapid advancements in analysis of polysomnography (Haghighat et al., 2025; Han & Oh, 2023; Hemrajani et al., 2023; M. J. Park et al., 2024). ML models using demographic, clinical, and questionnaire data (e.g., BMI, age, ESS) can predict OSA severity with moderate to high accuracy. Recent studies show that ML models—such as support vector machines, gradient boosting, random forests, and neural networks—can stratify OSA severity with accuracies ranging from 76% to over 91% for moderate and severe OSA (Ferreira-Santos et al., 2022; Liu et al., 2024). The most predictive variables used in ML algorithms include BMI, neck and waist circumference, age, ESS, and questionnaire scores (Dai et al., 2024). ML models using clinical, anatomical, and polysomnographic features can predict which patients will respond to oral appliance therapy, achieving up to 91% accuracy in some studies (Dutta et al., 2022; Vena et al., 2020). All these possibilities that AI and ML provide account for them being checked as a tool for modelling a personalized OSA therapy. ML models can predict which patients will benefit from specific treatments (e.g., CPAP, oral appliances, surgery). AI/ML models analyze data from CPAP devices (usage hours, mask leaks, pressure, etc.) to continuously track adherence. AI/ML can segment patients into adherence risk groups and trigger targeted interventions (e.g., phone calls, app notifications, equipment changes (Eguchi et al., 2022; Joy Mangul et al., 2023; Turino et al., 2021).

7. Challenges and limitations

While OSA has been proven to be a highly prevalent disorder, even nowadays it faces the problem of underdiagnosing. Up to 75–93% of adults with OSA remain undiagnosed (Fuhrman et al., 2012; Young et al., 2004). The global burden is immense, with nearly 1 billion people affected (Punjabi, 2008; Tufik et al., 2010; Zasadzińska-Stempniak et al., 2024). There are several key causes underlying, one of them being insufficient awareness. Many people are unfamiliar with OSA, its symptoms, and its serious health consequences. It is mostly since OSA symptoms are not specific. OSA commonly causes symptoms like excessive daytime sleepiness, fatigue, poor concentration, mood changes, and headaches. These are also frequent in depression, anxiety, insomnia, chronic pain, and other sleep or medical disorders; therefore, it is difficult to attribute them solely to OSA (Vanek et al., 2020; Verbraecken, 2022). What is more, OSA often coexists with other diseases. It is being strongly associated with hypertension, which is the most prevalent comorbidity. Frequent cardiovascular comorbidities also include coronary artery disease, arrhythmias, heart failure and stroke. Metabolic disorders such as diabetes mellitus, dyslipidemia have been prevalent (André et al., 2020; Pinto et al., 2016; Rincón-Hernández et al., 2025). Obesity is also highly prevalent (Bikov et al., 2020).

Table 3. Diseases coexisting with OSA and their prevalence

Comorbid disease	Prevalence range	Sources
Hypertension	39–59%	(André et al., 2020; Pinto et al., 2016; Rincón-Hernández et al., 2025)
Cardiovascular disease	24–52%	(André et al., 2020; Pinto et al., 2016; Rincón-Hernández et al., 2025)
Diabetes mellitus	15–22%	(André et al., 2020; Pinto et al., 2016; Rincón-Hernández et al., 2025)
Dyslipidemia	10–27%	(André et al., 2020; Pinto et al., 2016)
Obesity	30%+	(André et al., 2020; Pinto et al., 2016)
COPD	11–23%	(Bikov et al., 2020; Czerwaty et al., 2022; Rincón-Hernández et al., 2025)
Asthma	4–70%	(Antonaglia, 2022; Ragnoli et al., 2021)

Further issue to be discussed is poor adherence. Studies have shown that initial acceptance of CPAP is suboptimal; up to half of patients prescribed CPAP either refuse to start or discontinue early, with acceptance rates ranging from 28% to 80% depending on the population and setting (Al-Abri et al., 2020; Aurora et al., 2010; C. H. K. Lee et al., 2017). Long-term adherence rates are no better, as only about 40–60% of patients remain adherent (using CPAP ≥ 4 hours/night on $\geq 70\%$ of nights) after several months to years (Baratta et al., 2018; Gabryelska et al., 2021). Patients struggle with acceptance and long-term adherence due to a range of barriers. Key barriers include mask discomfort, poor fit, and air leaks, which are most frequently reported. Nasal symptoms such as dryness, congestion, and rhinorrhoea, as well as pressure-related side effects and claustrophobia, further reduce adherence (Baratta et al., 2018). Another aspect that should be taken into account are socioeconomic and systemic barriers. Lower household income is strongly associated with reduced CPAP adherence. Patients from lower-income backgrounds are less likely to use CPAP regularly, especially in healthcare systems where patients must pay out-of-pocket for devices and supplies. Lack of insurance coverage or restrictive policies (such as strict adherence requirements for continued coverage) can prevent patients from accessing or maintaining CPAP therapy (Johnson & Raphaelson, 2023; Palm et al., 2021). Another problem that makes OSA a particular challenge is the fact that there are no worldwide standardized methods or algorithms for selecting OSA patients suitable for upper airway (UA) surgery. Decisions are often based on the surgeon's preference, experience, and available local technology. Existing guidelines and algorithms are often institution-specific or based on expert consensus rather than high-quality evidence and are not intended to define standards of care or absolute requirement. Many new surgical techniques and modifications have been introduced, but their application is inconsistent, and the criteria for choosing among them are not standardized. Patient selection is frequently based only on anatomical characteristics, identified by different and sometimes unvalidated methods. Non-anatomical traits (such as loop gain and arousal threshold) are not routinely assessed, even though they can significantly affect surgical outcomes (Aurora et al., 2010; De Vito et al., 2021; Memtsoudis et al., 2018). As far as outcomes are concerned, there is a

widespread problem with outcome reporting, which is often limited and biased. Surgical outcomes are often reported using only AHI improvement, without considering other important parameters like daytime sleepiness or quality of life (De Vito et al., 2021).

8. Discussion

OSA is one of the most prevalent sleep-related breathing disorders and represents a significant public health concern with well-documented clinical implications. Numerous studies indicate that OSA is an independent risk factor for cardiovascular, metabolic, and neurological complications, contributing to increased morbidity and mortality in the adult population (H. P. Chang et al., 2020; Jordan et al., 2014). The complex pathophysiology of the disorder involves both anatomical factors, such as upper airway collapse during sleep, and functional mechanisms, including disturbances in ventilatory control referred to as elevated loop gain, which accounts for the considerable clinical heterogeneity of the disease (H. P. Chang et al., 2020; Jordan et al., 2014).

Contemporary approaches to OSA increasingly emphasize the need for patient phenotyping and individualized treatment within the framework of precision medicine. Epidemiological and clinical studies confirm that the diversity of pathophysiological mechanisms influences both the clinical presentation and the response to therapy (H. P. Chang et al., 2020). Symptoms of OSA are often nonspecific, which significantly complicates diagnosis.

A strong association between OSA and cardiovascular diseases, including arterial hypertension, coronary artery disease, and cardiac arrhythmias, has been repeatedly demonstrated (Milleron, 2018; Yuan et al., 2021). Of particular clinical significance is that up to 75% of cases of resistant hypertension may be attributable to underlying OSA (Mashaqi & Gozal, 2019). The mechanisms underlying these complications include chronic sympathetic nervous system activation, recurrent hypoxemia, and increased negative intrathoracic pressure, leading to myocardial remodeling and an elevated risk of heart failure (Bradley & Floras, 2003). OSA also increases the risk of stroke and worsens outcomes following cerebrovascular events, while CPAP therapy can significantly improve cognitive function and post-stroke rehabilitation outcomes (Aaronson et al., 2015; Bravata et al., 2010).

Despite its high prevalence, OSA remains largely underdiagnosed. It is estimated that 75% to 93% of affected adults have not received a formal diagnosis (Fuhrman et al., 2012; Young et al., 2004). In a large Canadian study, only 1.2% of individuals identified as high-risk had a clinical diagnosis of OSA (Rizzo et al., 2024).

Polysomnography remains the gold standard for diagnosis, although home sleep tests and screening questionnaires, such as STOP-Bang, NoSAS, and ESS, are increasingly being used (J. L. Chang et al., 2023; Laratta et al., 2017). However, it should be emphasized that the sensitivity and specificity of home sleep tests are lower compared to laboratory polysomnography, particularly in patients with comorbid conditions (Victor, 1999), in the pediatric population, polysomnography remains an essential diagnostic tool (Bitners & Arens, 2020).

CPAP therapy continues to be the cornerstone of OSA treatment, effectively reducing AHI, improving sleep quality, and lowering the risk of cardiovascular complications (Rahman et al., 2024; Sulina et al., 2025). However, one of the greatest clinical challenges remains low acceptance and poor long-term adherence. Approximately half of patients either do not initiate therapy or discontinue it prematurely, and only 40–60% meet the criteria for effective CPAP use after several months or years (Al-Abri et al., 2020; Aurora et al., 2010; C. H. K. Lee et al., 2017). In the pediatric population, these adherence rates are even lower, averaging around 46% (Baratta et al., 2018; Gabryelska et al., 2021). The main barriers include mask-related discomfort, nasal symptoms, pressure-related side effects, and claustrophobia (Baratta et al., 2018).

Alternative treatment methods, such as auto-CPAP, BiPAP, or mandibular advancement devices, demonstrate comparable efficacy in selected patient groups and may enhance therapy comfort (Benke et al., 2021; Nanda et al., 2025; Palot et al., 2023; Yu et al., 2023). Surgical treatment remains an option for patients intolerant to conservative therapy; however, standardized international guidelines for upper airway surgical selection are still lacking. Therapeutic decisions are often based on the surgeon's experience and the availability of local technologies rather than on high-quality scientific evidence (Aurora et al., 2010; De Vito et al., 2021; Memtsoudis et al., 2018).

Modern approaches, such as DISE, HGNS, and the application of AI and ML, offer new opportunities for personalizing the diagnosis and treatment of OSA (Alrubasy et al., 2024; Haghighat et al., 2025; Han & Oh, 2023; Kent et al., 2019; Pereira & Ribeiro, 2022; Wang et al., 2024). AI algorithms achieve high diagnostic

accuracy and can support the prediction of treatment effectiveness as well as adherence monitoring (Joymangul et al., 2023; Turino et al., 2021).

In summary, OSA remains a disorder with a complex etiology, substantial epidemiological significance, and a considerable impact on public health. Early diagnosis, increased public awareness, individualized treatment, and the integration of modern technologies with conventional diagnostic and therapeutic approaches are key elements in improving prognosis and quality of life for patients. (Jordan et al., 2014; Mashaqi et al., 2021).

10. Conclusions

1. **Diagnostics:** The high percentage of underdiagnosed patients (80–90%) indicates the need to implement validated tools for more accessible and effective OSA screening in primary care settings.

2. **Personalization of Treatment:** The complex pathophysiology of OSA (anatomical vs. functional factors) requires a shift from a "one-size-fits-all" approach to individualized therapy. The selection of treatment methods— intraoral appliances, pharmacotherapy, or lifestyle modification—should be based on patient phenotyping to overcome poor adherence.

3. **Multidisciplinary Care:** The systemic consequences of OSA (cardiovascular, metabolic, and neurocognitive complications) require integrated management and collaboration between pulmonologists, cardiologists, neurologists, and sleep medicine specialists to effectively reduce long-term sequelae and improve patients' quality of life.

Ethics Approval and Consent to Participate: Not applicable. This study is a narrative review and does not involve human participants or animals.

Availability of Data and Material: Not applicable. This study is a narrative review and does not include original data.

Competing Interests: The authors declare no conflicts of interest.

Funding: This research received no external funding.

Authors' Contributions: Julia Rydzek, Marta Zawadzka, Adrian Muzyka, Zuzanna Krupa, and Joanna Wrona contributed to the conceptualization of the study. Joanna Wrona developed the methodology. Julia Rydzek, Adrian Muzyka, Zuzanna Krupa, and Joanna Wrona prepared the original draft of the manuscript. Marta Zawadzka and Karolina Dorobisz critically revised and edited the manuscript. Julia Rydzek, Marta Zawadzka, Adrian Muzyka, Zuzanna Krupa, and Joanna Wrona contributed to resources. Karolina Dorobisz supervised the project. All authors reviewed and approved the final version of the manuscript.

REFERENCES

1. Aaronson, J. A., Van Bennekom, C. A. M., Hofman, W. F., Van Bezeij, T., Van Den Aardweg, J. G., Groet, E., Kylstra, W. A., & Schmand, B. (2015). Obstructive sleep apnea is related to impaired cognitive and functional status after stroke. *Sleep*, 38(9), 1431–1437B. <https://doi.org/10.5665/SLEEP.4984>
2. Abad, V. C. (2021). Profile of solriamfetol in the management of excessive daytime sleepiness associated with narcolepsy or obstructive sleep apnea: Focus on patient selection and perspectives. *Nature and Science of Sleep*, 13, 75–91. <https://doi.org/10.2147/NSS.S245020>
3. Abd El-Aziz, A., Abd El-Fattah, A., El-Habashy, M., Omar, H., & Abd El Wahab, S. (2018). Effectiveness of septoplasty with or without inferior turbinate reduction in patients with obstructive sleep apnea. *The Egyptian Journal of Chest Diseases and Tuberculosis*, 67(3), 295. https://doi.org/10.4103/EJCDT.EJCDT_5_18
4. Al-Abri, M. A., Al-Harmeli, A., Al-Habsi, M., & Jaju, D. (2020). Acceptance and compliance of continuous positive airway pressure in patients with obstructive sleep apnea: Local population survey. *Oman Medical Journal*, 35(6), 1–6. <https://doi.org/10.5001/OMJ.2020.94>
5. Alrubasy, W. A., Abuawwad, M. T., Taha, M. J. J., Khurais, M., Sayed, M. S., Dahik, A. M., Keshk, N., Abdelhadi, S., & Serhan, H. A. (2024). Hypoglossal nerve stimulation for obstructive sleep apnea in adults: An updated systematic review and meta-analysis. *Respiratory Medicine*, 234. <https://doi.org/10.1016/j.rmed.2024.107826>
6. Amali, A., Motiee-Langroudi, M., Saedi, B., Rahavi-Ezabadi, S., Karimian, A., & Amirzargar, B. (2017). A comparison of uvulopalatopharyngoplasty and modified radiofrequency tissue ablation in mild to moderate obstructive sleep apnea: A randomized clinical trial. *Journal of Clinical Sleep Medicine*, 13(9), 1089–1096. <https://doi.org/10.5664/JCSM.6730>
7. André, S., Andreozzi, F., Van Overstraeten, C., Ben Youssef, S., Bold, I., Carlier, S., Gruwez, A., Bruyneel, A. V., & Bruyneel, M. (2020). Cardiometabolic comorbidities in obstructive sleep apnea patients are related to disease severity, nocturnal hypoxemia, and decreased sleep quality. *Respiratory Research*, 21(1). <https://doi.org/10.1186/S12931-020-1284-7>

8. Antonaglia, C. (2022). Obstructive sleep apnea syndrome (OSAS) and asthma: A simple association: A new syndrome or a cluster? *Journal of Biomedical Research & Environmental Sciences*, 3(8), 944–952. <https://doi.org/10.37871/jbres1537>
9. Asarkar, A. A., Bui, R., Calligas, J., Gillespie, M. B., & Nathan, C. A. O. (2024). Where does hypoglossal nerve stimulator implant fit in the surgical management algorithm of obstructive sleep apnea? *The Laryngoscope*, 134(10), 4165–4166. <https://doi.org/10.1002/LARY.31486>
10. Aurora, R. N., Casey, K. R., Kristo, D., Auerbach, S., Bista, S. R., Chowdhuri, S., Karipott, A., Lamm, C., Ramar, K., Zak, R., Morgenthaler, T. I., & Tracy, S. L. (2010). Practice parameters for the surgical modifications of the upper airway for obstructive sleep apnea in adults. *Sleep*, 33(10), 1408–1413. <https://doi.org/10.1093/SLEEP/33.10.1408>
11. Avatef Fazeli, M., Hedayati, A., Dehghani, A., Hedayati, M., & Zaremehrjardi, F. (2022). The effects of nasal septoplasty on the severity of obstructive sleep apnea syndrome: A quasi-experimental study. *Hospital Practices and Research*, 7(3), 105–108. <https://doi.org/10.34172/HPR.2022.21>
12. Baptista, P. M., Zufiaurre, N. D., Garaycochea, O., Navarrete, J. M. A., Moffa, A., Giorgi, L., Casale, M., O'Connor-Reina, C., & Plaza, G. (2022). TORS as part of multilevel surgery in OSA: The importance of careful patient selection and outcomes. *Journal of Clinical Medicine*, 11(4). <https://doi.org/10.3390/JCM11040990>
13. Baradaranfar, M. H., Edalatkhah, M., Dadgarnia, M. H., Atighechi, S., Behniafard, N., Mirvakili, A., Halvani, A., Baradaranfar, A., & Emami Meybodi, T. (2015). The effect of uvulopalatopharyngoplasty with tonsillectomy in patients with obstructive sleep apnea. *Indian Journal of Otolaryngology and Head and Neck Surgery*, 67(Suppl 1), 29–33. <https://doi.org/10.1007/S12070-014-0735-1>
14. Baratta, F., Pastori, D., Bucci, T., Fabiani, M., Fabiani, V., Brunori, M., Loffredo, L., Lillo, R., Pannitteri, G., Angelico, F., & Del Ben, M. (2018). Long-term prediction of adherence to continuous positive air pressure therapy for the treatment of moderate/severe obstructive sleep apnea syndrome. *Sleep Medicine*, 43, 66–70. <https://doi.org/10.1016/J.SLEEP.2017.09.032>
15. Benke, S., Okorie, C. U. A., & Tablizo, M. A. (2021). The use of auto-titrating continuous positive airway pressure (AutoCPAP) for obstructive sleep apnea syndrome in children with obesity. *Children*, 8(12). <https://doi.org/10.3390/CHILDREN8121204>
16. Berg, L. M., Ankjell, T. K. S., Sun, Y.-Q., Trovik, T. A., Sjögren, A., Rikardsen, O. G., Moen, K., Hellem, S., & Bugten, V. (2020). Friedman score in relation to compliance and treatment response in nonsevere obstructive sleep apnea. *International Journal of Otolaryngology*, 2020, 1–8. <https://doi.org/10.1155/2020/6459276>
17. Bikov, A., Frent, S., Pleava, R., Kunos, L., Bokhari, S., Meszaros, M., & Mihaicuta, S. (2020). The burden of associated comorbidities in patients with obstructive sleep apnea—Regional differences in two Central-Eastern European sleep centers. *Journal of Clinical Medicine*, 9(11). <https://doi.org/10.3390/JCM9113583>
18. Bitners, A. C., & Arens, R. (2020). Evaluation and management of children with obstructive sleep apnea syndrome. *Lung*, 198(2), 257–270. <https://doi.org/10.1007/S00408-020-00342-5>
19. Boudewyns, A., Verhulst, S., Maris, M., Saldien, V., & Van de Heyning, P. (2014). Drug-induced sedation endoscopy in pediatric obstructive sleep apnea syndrome. *Sleep Medicine*, 15(12), 1526–1531. <https://doi.org/10.1016/J.SLEEP.2014.06.016>
20. Bradley, T. D., & Floras, J. S. (2003). Sleep apnea and heart failure: Part II: Central sleep apnea. *Circulation*, 107(13), 1822–1826. <https://doi.org/10.1161/01.CIR.0000061758.05044.64>
21. Brander, P. E., Soirinsuo, M., & Lohela, P. (1999). Nasopharyngeal symptoms in patients with obstructive sleep apnea syndrome: Effect of nasal CPAP treatment. *Respiration; International Review of Thoracic Diseases*, 66(2), 128–135. <https://doi.org/10.1159/000029354>
22. Bravata, D. M., Concato, J., Fried, T., Ranjbar, N., Sadarangani, T., McClain, V., Struve, F., Zygmunt, L., Knight, H. J., Lo, A., Richerson, G. B., Gorman, M., Williams, L. S., Brass, L. M., Agostini, J., Mohsenin, V., Roux, F., & Yaggi, H. K. (2010). Auto-titrating continuous positive airway pressure for patients with acute transient ischemic attack: A randomized feasibility trial. *Stroke*, 41(7), 1464–1470. <https://doi.org/10.1161/STROKEAHA.109.566745>
23. Camañes-Gonzalvo, S., Bellot-Arcís, C., Marco-Pitarch, R., Montiel-Company, J. M., García-Selva, M., Agustín-Panadero, R., Paredes-Gallardo, V., & Puertas-Cuesta, F. J. (2022). Comparison of the phenotypic characteristics between responders and non-responders to obstructive sleep apnea treatment using mandibular advancement devices in adult patients: Systematic review and meta-analysis. *Sleep Medicine Reviews*, 64. <https://doi.org/10.1016/j.smrv.2022.101644>
24. Cao, X., Zhou, Y., Zhang, J., Yin, G., & Ye, J. (2023). Application of drug-induced sleep endoscopy in predicting the outcomes of velopharyngeal surgery in adult patients with Friedman stage II and III obstructive sleep apnea syndrome. *Frontiers in Neurology*, 13. <https://doi.org/10.3389/FNEUR.2022.1049425>
25. Carneiro-Barrera, A., Amaro-Gahete, F. J., Guillén-Riquelme, A., Jurado-Fasoli, L., Sáez-Roca, G., Martín-Carrasco, C., Buéla-Casal, G., & Ruiz, J. R. (2022). Effect of an interdisciplinary weight loss and lifestyle intervention on obstructive sleep apnea severity: The INTERAPNEA randomized clinical trial. *JAMA Network Open*, 5(4), e228212. <https://doi.org/10.1001/JAMANETWORKOPEN.2022.8212>

26. Chang, H. P., Chen, Y. F., & Du, J. K. (2020). Obstructive sleep apnea treatment in adults. *The Kaohsiung Journal of Medical Sciences*, 36(1), 7–12. <https://doi.org/10.1002/KJM2.12130>
27. Chang, J. L., Goldberg, A. N., Alt, J. A., Mohammed, A., Ashbrook, L., Auckley, D., Ayappa, I., Bakhtiar, H., Barrera, J. E., Bartley, B. L., Billings, M. E., Boon, M. S., Bosschietter, P., Braverman, I., Brodie, K., Cabrera-Muffly, C., Caesar, R., Cahali, M. B., Cai, Y., ... Rosen, I. M. (2023). International consensus statement on obstructive sleep apnea. *International Forum of Allergy & Rhinology*, 13(7), 1061–1482. <https://doi.org/10.1002/ALR.23079>
28. Chung, F., Abdullah, H. R., & Liao, P. (2016). STOP-Bang questionnaire: A practical approach to screen for obstructive sleep apnea. *Chest*, 149(3), 631–638. <https://doi.org/10.1378/CHEST.15-0903>
29. Czerwaty, K., Dżaman, K., Sobczyk, K. M., & Sikorska, K. I. (2022). The overlap syndrome of obstructive sleep apnea and chronic obstructive pulmonary disease: A systematic review. *Biomedicines*, 11(1). <https://doi.org/10.3390/BIOMEDICINES11010016>
30. da Cunha Viana, A., Mendes, D. L., de Andrade Lemes, L. N., Thuler, L. C. S., Neves, D. D., & de Araújo-Melo, M. H. (2017). Drug-induced sleep endoscopy in the obstructive sleep apnea: Comparison between NOHL and VOTE classifications. *European Archives of Oto-Rhino-Laryngology*, 274(2), 627–635. <https://doi.org/10.1007/S00405-016-4081-7>
31. Dai, R., Yang, K., Zhuang, J., Yao, L., Hu, Y., Chen, Q., Zheng, H., Zhu, X., Ke, J., Zeng, Y., Fan, C., Chen, X., Fan, J., & Zhang, Y. (2024). Enhanced machine learning approaches for OSA patient screening: Model development and validation study. *Scientific Reports*, 14(1). <https://doi.org/10.1038/S41598-024-70647-5>
32. De Vito, A., Woodson, B. T., Koka, V., Cammaroto, G., Iannella, G., Bosi, M., Pelucchi, S., Filograna-Pignatelli, G. R., Chater, P. El, & Vicini, C. (2021). OSA upper airways surgery: A targeted approach. *Medicina*, 57(7). <https://doi.org/10.3390/MEDICINA57070690>
33. Dutta, R., Tong, B. K., & Eckert, D. J. (2022). Development of a physiological-based model that uses standard polysomnography and clinical data to predict oral appliance treatment outcomes in obstructive sleep apnea. *Journal of Clinical Sleep Medicine*, 18(3), 861–870. <https://doi.org/10.5664/JCSM.9742>
34. Eguchi, K., Yabuuchi, T., Nambu, M., Takeyama, H., Azuma, S., Chin, K., & Kuroda, T. (2022). Investigation on factors related to poor CPAP adherence using machine learning: A pilot study. *Scientific Reports*, 12(1). <https://doi.org/10.1038/S41598-022-21932-8>
35. Ferreira-Santos, D., Amorim, P., Martins, T. S., Monteiro-Soares, M., & Rodrigues, P. P. (2022). Enabling early obstructive sleep apnea diagnosis with machine learning: Systematic review. *Journal of Medical Internet Research*, 24(9). <https://doi.org/10.2196/39452>
36. Friedman, M., Salapatas, A. M., & Bonzelaar, L. B. (2017). Updated Friedman staging system for obstructive sleep apnea. *Advances in Oto-Rhino-Laryngology*, 80, 41–48. <https://doi.org/10.1159/000470859>
37. Fuhrman, C., Fleury, B., Nguyễn, X. L., & Delmas, M. C. (2012). Symptoms of sleep apnea syndrome: High prevalence and underdiagnosis in the French population. *Sleep Medicine*, 13(7), 852–858. <https://doi.org/10.1016/J.SLEEP.2012.04.005>
38. Gabryelska, A., Sochal, M., Wasik, B., Szczepanowski, P., & Białasiewicz, P. (2021). Factors affecting long-term compliance of CPAP treatment—A single centre experience. *Journal of Clinical Medicine*, 11(1). <https://doi.org/10.3390/JCM11010139>
39. Georgakopoulou, V., Pantazis, N., Tsiafaki, X., Nena, E., Amfilochiou, A., & Steiropoulos, P. (2023). Validation of NoSAS score for the screening of obstructive sleep apnea. *Medicine International*, 3(2). <https://doi.org/10.3892/MI.2023.74>
40. Georgoulis, M., Yiannakouris, N., Kechribari, I., Lamprou, K., Perraki, E., Vagiakis, E., & Kontogianni, M. D. (2021). The effectiveness of a weight-loss Mediterranean diet/lifestyle intervention in the management of obstructive sleep apnea: Results of the “MIMOSA” randomized clinical trial. *Clinical Nutrition*, 40(3), 850–859. <https://doi.org/10.1016/J.CLNU.2020.08>