ZIELONKA, Kacper, JASIŃSKA, Joanna, DĄDELA, Bartosz, MARKOWSKI, Marcin, ŚLIWA, Natalia, MAJEWSKA, Emilia Maria, KAWALSKA, Eliza, GNITECKI, Szymon, JANCZURA, Szymon and BOROWSKI, Maciej. A Review of Obstructive Sleep Apnea Treatment: The Role of Surgery in Therapy and Alternative Treatment Modalities. Quality in Sport. 2025;40:59647. eISSN 2450-3118.
https://doi.org/10.12775/QS.2025.40.59647
https://apcz.umk.pl/QS/article/view/59647

The journal has been 20 points in the Ministry of Higher Education and Science of Poland parametric evaluation. Annex to the announcement of the Minister of Higher Education and Science of 05.01.2024. No. 32553.
Has a Journal's Unique Identifier: 201398. Scientific disciplines assigned: Economics and finance (Field of social sciences); Management and Quality Sciences (Field of social sciences).
Punkty Ministerialne z 2019 - aktualny rok 20 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 r. Lp. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398.
Przypisane dyscypliny naukowe: Ekonomia i finanse (Dziedzina nauk społecznych); Nauki o zarządzaniu i jakości (Dziedzina nauk społecznych).

The authors declare that there is no conflict of interests regarding the publication of this paper.
Received: 20.03.2025. Revised: 21.03.2025. Accepted: 04.04.2025 Published: 10.04.2025.

A Review of Obstructive Sleep Apnea Treatment: The Role of Surgery in Therapy and Alternative Treatment Modalities

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Abstract
Obstructive sleep apnea (OSA) is a common sleep disorder involving repeated upper airway obstructions during sleep, leading to hypoxia, fragmented sleep, and excessive daytime sleepiness. It is linked to significant cardiovascular and metabolic risks and affects 17-30% of individuals aged 30-69, with higher rates in the elderly. Diagnosis is typically made using polysomnography, which assesses the frequency and severity of apneic events.
Treatment mainly involves continuous positive airway pressure (CPAP), although adherence can be challenging. Alternative therapies like oral appliances, positional therapy, and lifestyle modifications are helpful for milder cases. Medications such as GLP-1 receptor agonists, acetazolamide and 5-HT regulating have shown promise in reducing symptoms and improving CPAP compliance.
Surgical options, such as uvulopalatopharyngoplasty (UPPP), maxillomandibular advancement (MMA), transoral robotic surgery (TORS) and tracheostomy, are considered when other treatments fail, particularly in patients with anatomical issues. Bariatric surgery can also reduce OSA severity in severely obese patients. Emerging therapies like hypoglossal nerve stimulation (HGNS), orofacial myofunctional therapy (OMT), and cognitive behavioral therapy for insomnia (CBT-I) offer solutions for patients who cannot tolerate CPAP. Advancements in AI and telemedicine are improving diagnosis and treatment personalization.
OSA treatment requires a tailored approach, considering individual factors and comorbidities. Continued research is essential to optimize long-term care.

Keywords: obstructive sleep apnea (OSA); continous positive airway pressure (CPAP); surgical treatment; upper airway surgery; alternative therapies

Introduction

Obstructive sleep apnea (OSA) is a prevalent and potentially dangerous sleep disorder, characterized by recurrent episodes of partial or complete obstruction of the upper airway during sleep. These obstructions lead to intermittent airflow reduction or cessation, resulting in hypoxemia and fragmentation of the sleep cycle (Russo et al. 2025; Prakash et al., 2025; Fabozzi et al., 2025; Qureshi et al., 2003; Rundo, 2019; Gottlieb & Punjabi, 2020; Mannarino et al., 2012). Typical clinical manifestations of OSA include loud and frequent snoring, episodes of nocturnal gasping or choking, excessive daytime somnolence, morning headaches, and increased irritability (Segna et al., 2025; Kaddoura et al, 2025). The intermittent nature of airway obstruction in OSA can significantly disrupt normal sleep architecture, contributing to significant daytime functional impairment (Hsu et al., 2024; Padovano et al., 2025; Portelli et al., 2024).
OSA is a major cause of cardiovascular morbidity and mortality, contributing to conditions such as hypertension, arrhythmias, stroke, and heart failure (Prakash et al., 2025; Badran et al., 2023; Rana et al., 2020; Mannarino et al., 2012; Kapur, 2010). It is often associated with other medical

conditions and metabolic complications, such as obesity or diabetes (Russo et al., 2025). Diagnosis typically involves polysomnography to assess the frequency and severity of apneic episodes (Qureshi et al., 2003; Rundo, 2019; Mannarino et al., 2012).

Recent studies highlight the significant global prevalence of OSA. A systematic review by Fabozzi et al. (2025) reported that, among individuals aged 30–69 years, the prevalence of OSA ranges from 17% to 30%, with a diagnosis threshold of ≥15 events per hour on the apnea-hypopnea index (AHI). This prevalence increases notably in the elderly population, where it reaches between 36% and 50% (Fabozzi et al., 2025). Furthermore, Gunel et al. (2025) revealed that a large population-based study in Europe found that 61% of women and 84% of men were affected by OSA in an unselected sample of 1525 adults. Globally, OSA is estimated to impact over 930 million adults, emphasizing the widespread nature of this condition (Gunel et al., 2025; Lyons et al., 2020; Benjafeld et al., 2019). This age-related rise is attributed to several factors, including an increase in oropharyngeal airway resistance and a reduction in upper airway dimensions, both of which are exacerbated by the natural aging process (Fabozzi et al., 2025).

Effective management of OSA is critical to improving patient outcomes. While Continuous Positive Airway Pressure (CPAP) therapy remains the gold standard for moderate to severe cases, adherence is often challenging due to issues of compliance and patient discomfort (Himejima et al., 2025; Slowik et al., 2024). Surgical interventions, along with non-invasive alternatives, have emerged as important adjuncts to standard therapy, particularly for patients with specific anatomical factors or those who do not respond to CPAP treatment (Cohen et al., 2025; Hsu et al., 2024).

This review aims to provide a comprehensive evaluation of the treatment options for OSA, focusing on the role of surgery in therapy and exploring the latest advancements in alternative modalities.

Treatment of Obstructive Sleep Apnea: Pharmacological and Non-Pharmacological Approaches

Non-Pharmacological and Conservative Treatment

Continuous Positive Airway Pressure (CPAP) Therapy

CPAP therapy is widely recognized as the gold standard for treating moderate to severe obstructive sleep apnea (Tan et al., 2025; Alluri et al., 2025; Sarkez-Knudsen et al., 2025; Elhaddaoui et al., 2025). The mechanism of CPAP involves delivering a continuous stream of pressurized air through a mask worn during sleep, which maintains the patency of the upper airway by preventing its collapse (Ayoub et al., 2025). The therapeutic pressure should be determined individually for each patient based on the results of manual titration or, more commonly, home titration using an automatic CPAP device over several nights (Park et al., 2025). The mask should fit properly to avoid leaks, with nasal masks preferred over oronasal masks (Gambino et al., 2022).

Indications and Effectiveness: CPAP is indicated for patients with an apnea-hypopnea index (AHI) of 15 or more events per hour, as well as for those with milder OSA (AHI 5–15) who experience excessive daytime sleepiness or other comorbidities (Pevernagie et al, 2020). CPAP has been shown to significantly reduce AHI, improve daytime sleepiness, and enhance overall quality of life. It is also effective in mitigating cardiovascular risks associated with OSA (Gunel et al., 2025).

Oral Appliance Therapy

Oral appliance therapy (OAT) is a widely recognized non-pharmacological treatment for obstructive sleep apnea (OSA). Among the most commonly used oral appliances are mandibular advancement devices (MADs) and tongue-retaining devices (TRDs), particularly beneficial for patients with mild to moderate OSA or those intolerant to continuous positive airway pressure (CPAP) therapy (Elhaddaoui et al., 2025; Tan et al., 2025; Gunel et al., 2025; Rudolph, 2025). Zhou et al. (2025) and Leibovitz et al. (2025) suggest that MADs may serve as an alternative for severe OSA patients intolerant to CPAP, though with lower efficacy. It can be used as a functional second line treatment option to CPAP (Tan et al., 2025; Gunel et al., 2025; Rathesha et al., 2025). Certain designs can provide highly effective non-CPAP treatment options (Liptak et al., 2025).

MADs function by repositioning the lower jaw forward, thus increasing the volume of the upper airway and preventing its collapse during sleep. MADs vary in design, including single-block, two-block, prefabricated, and custom-made models, each tailored to the individual patient's anatomical needs. Custom-made MADs tend to offer superior comfort and efficacy, providing better therapeutic outcomes compared to prefabricated devices (Gunel et al., 2025; Tan et al., 2025).

TRDs, designed to hold the tongue in a slightly forward position, effectively reduce oropharyngeal obstruction by preventing the tongue from collapsing into the airway. Although TRDs may offer significant benefits, including a 53% reduction in the apnea-hypopnea index (AHI), their use is less common compared to MADs (Gunel et al., 2025).

Both MADs and TRDs have been shown to effectively decrease the severity of sleep apnea and alleviate excessive daytime sleepiness (Rudolph, 2025). However, the effectiveness of MAD therapy can vary based on the degree of mandibular advancement, with higher advancements generally yielding better results, although extreme advancements may increase the risk of side effects (Gunel et al., 2025). While MADs have been shown to be effective in improving AHI and oxygen saturation, long-term use may lead to complications such as tooth movement and occlusal changes, necessitating careful monitoring and occasional adjustment of the device (Taga et al., 2025).

Positional Therapy and Lifestyle Modifications

Positional therapy aims to prevent patients from sleeping in the supine position, which can exacerbate OSA symptoms. Various positional therapy devices, ranging from simple techniques like tennis balls sewn into the back of sleepwear to more sophisticated devices such as vibrating

alarms and specialized pillows, have been developed to address this issue and to encourage side sleeping (Gao et al., 2025; Mackay et al., 2025; Rathesha et al., 2025). Additionally, lifestyle modifications play a crucial role in managing OSA. Weight loss, particularly in obese individuals, can significantly reduce the severity of OSA. A 10%-15% reduction in body weight can lead to a 30%-50% decrease in AHI (Mackay et al., 2025; Rudolph, 2025).

Sleep positional therapy (SPT) is a safe alternative for managing positional OSA, particularly for patients intolerant to CPAP, though it remains less effective than CPAP in reducing overall AHI and improving oxygenation (Gao et al., 2025; Rathesha et al., 2025).

Given that obesity is a major risk factor for OSA, weight loss remains an important treatment strategy for many OSA patients. Studies have demonstrated that weight loss through various methods can significantly impact OSA severity, although dramatic weight loss may not completely resolve the condition (Mackay et al., 2025).

Additional Lifestyle Recommendations:

Maintaining a high dietary quality and engaging in regular physical activity significantly reduces the risk of obstructive sleep apnea (OSA). Avoiding alcohol and sedatives, especially in the evening, is crucial as they can worsen OSA by relaxing throat muscles. Smoking cessation is also important, as smoking can cause inflammation and fluid retention in the upper airway. These lifestyle changes, combined with a balanced diet and regular exercise, are essential for preventing and managing OSA (Zuo & Yang, 2025; Rudolph, 2025).

Dietary Interventions

In addition to weight loss, specific dietary components may play a beneficial role in managing OSA. Proteins, carbohydrates, anti-inflammatory agents, and vitamins A, B, C, D, and E have been shown to influence the incidence and severity of OSA. Dietary adjustments, such as reducing carbohydrate consumption, can help control body mass and improve sleep-related parameters, potentially mitigating the pathogenesis of OSA (Archontogeorgis et al., 2025; Shi et al., 2025).

Pharmacological Treatment

Role of Medications in OSA Management

While CPAP remains the first-line treatment for OSA, pharmacological interventions are increasingly being explored as adjunctive or alternative therapies. Medications can be particularly useful in cases where CPAP is not well-tolerated or in addressing comorbid conditions that exacerbate OSA. Pepin et al., (2022) and Lisik & Zou (2025) highlight that many patients express a strong preference for non-device-based pharmacological treatments. Recent research indicates that there are several promising therapeutic targets for pharmacotherapy in the management of OSA.

GLP-1 Receptor Agonists (GLP-1 Ras)

GLP-1 RAs, originally developed for managing type 2 diabetes and obesity, have shown promise in reducing OSA symptoms. These drugs promote weight loss by reducing fat deposits around the upper airway, which can alleviate airway obstruction and lower the need for high CPAP pressure (El-Solh et al., 2024). Emerging evidence suggests that GLP-1 RAs may offer therapeutic benefits in managing OSA, particularly by addressing obesity, a key contributor to the condition (Alluri et al., 2025). Tirzepatide (GIP and GLP-1 dual agonists) treatment is posited to provide weight reduction with improved body composition and associated improvements in cardiovascular risk markers, addressing the underlying cause of obesity-related OSA (Malhotra et al., 2024; Lisik & Zou, 2025; Wen et al., 2025). However, GLP-1 RAs are not a substitute for CPAP therapy and should be used in conjunction with lifestyle modifications (Drager, 2025).

Chinese Herbal Medicine (CHM)

Recent studies have indicated that CHM, either alone or in combination with CPAP, can improve various aspects of OSA, including AHI, sleepiness, and quality of life. CHM has been shown to reduce AHI more significantly than placebo and enhance the effectiveness of CPAP when used together (Birling et al., 2025).

Acetazolamide

Combining acetazolamide with CPAP has been found to significantly improve OSA outcomes, including reductions in total AHI and non-REM AHI. This combination therapy also enhances sleep architecture and reduces daytime somnolence, with minimal side effects (Tripathi et al., 2025).

5-HT Regulating Medications

The 5-HT regulating medications, such as buspirone and trazodone, have shown potential in managing OSA by reducing the AHI index and improving psychiatric comorbidities and cognitive decline symptoms. However, side effects like weight gain may limit their efficacy (Witkowska et al., 2024).

Other Pharmacological Approaches

Excessive daytime sleepiness (EDS) is a prominent symptom of OSA, affecting 40.5%–58% of patients. Wake-promoting agents (WPAs) such as modafinil, armodafinil, solriamfetol, and pitolisant have demonstrated considerable efficacy in managing residual EDS in treated patients with OSA (Wang et al., 2024), with solriamfetol likely being superior (Pitre et al., 2023). Atomoxetine plus oxybutynin can improve upper airway collapsibility and decrease arousal threshold (Gunel et al., 2025). The combination of noradrenergic and antimuscarinic agents has shown a positive, yet modest, impact on reducing the severity of obstructive sleep apnea. This therapeutic regimen is most effective in male OSA patients. The combined treatment may be used as an alternative, adjunctive, salvage, or synergistic option, but its use should be carefully considered, taking into account possible side effects (Lee et al., 2025).

The Role of Surgery in the Treatment of Obstructive Sleep Apnea

Indications for Surgical Treatment

Surgical intervention for obstructive sleep apnea (OSA) is considered when other therapeutic methods, such as continuous positive airway pressure (CPAP), fail or are not tolerated by the patient (Bègue et al., 2025; Torabi et al., 2025; De Vito et al., 2021). Anatomical abnormalities in the upper airway, including significant nasal obstruction, tonsillar hypertrophy, and craniofacial deformities, are primary indications for surgical correction (Elhaddaoui et al., 2025). Additionally, surgical options are explored for patients with severe OSA who have significant comorbidities or those who prefer surgery over other treatment modalities (Mackay et al., 2025).

Types of Surgical Procedures

Upper Airway Surgery

Uvulopalatopharyngoplasty (UPPP) is the most common surgical procedure (Fleury Curado et al., 2025) which involves the removal or remodeling of soft tissue in the throat, including the uvula, soft palate, and tonsils. This procedure aims to widen the airway and reduce obstruction (De Vito et al., 2021). However, its effectiveness varies, with success rates ranging from 38.71% to 59.26% (Vlad et al., 2023). Modified UPPP (mUPPP) has shown improved outcomes when combined with other procedures, such as radiofrequency coblation inferior turbinoplasty (Tian et al., 2025).

Pharyngoplasty Techniques:

Barbed Reposition Pharyngoplasty (BRP) is a highly effective and safe velopharyngeal technique that involves repositioning pharyngeal tissues to stabilize the airway (Vlad et al., 2023). Post-BRP, improvements in the Apnea-Hypopnea Index (AHI) correlate with enhanced deep sleep and reduced light sleep, although REM sleep remains relatively unchanged (Moffa et al., 2025). This suggests BRP as a valid surgical option for improving both respiratory health and sleep quality.

Expansion Sphincter Pharyngoplasty (ESP) is another effective technique that targets the lateral pharyngeal walls and has shown significant improvements in AHI (Vlad et al., 2023; De Vito et al., 2021).

Lateral Pharyngoplasty (LP) is a moderate technique that addresses lateral pharyngeal wall collapse and has shown variable success rates (Vlad et al., 2023; Emara et al., 2024).

Nasal Surgery

Nasal obstruction due to septal deviation or inferior turbinate hypertrophy can be addressed through septoplasty or radiofrequency coblation inferior turbinoplasty. These procedures aim to improve nasal airflow and reduce hypopneas (Gunel et al., 2025; Tian et al., 2025).

Tongue Base Surgery

Surgical reduction of the tongue base can be achieved through various techniques, including radiofrequency ablation and lingual tonsillectomy. These procedures are often considered in multilevel surgery to address tongue-related obstructions (Diemer et al., 2024).

Maxillomandibular Advancement (MMA)
MMA is considered the most effective surgical treatments for OSA (Al Bayyati et al., 2025; De Vito et al., 2021). It involves advancing both the maxilla and mandible to widen the upper airway, providing structural support and relieving airway collapse. MMA has shown high success rates and significant improvements in both subjective and objective OSA outcomes (Zhou et al., 2025; Diemer et al., 2024).

Tracheostomy
Tracheostomy, once the standard of care for severe obstructive sleep apnea (OSA) patients before the advent of CPAP, remains a vital intervention in select cases. It involves creating a surgical opening in the trachea to bypass upper airway obstructions, significantly reducing apnea index, oxygen desaturation, sleepiness, and mortality (Camacho et al., 2014; Camacho et al., 2016). While rarely needed (Segna et al., 2025), tracheostomy is used either as a permanent therapy for patients not amenable to other treatments or as a temporary measure for airway protection in high-risk perioperative settings (Zhou et al., 2025). Both tubed and tubeless tracheostomies are employed, highlighting the importance of individualized treatment plans (Camacho et al., 2016).

Transoral Robotic Surgery (TORS)
TORS is a common surgical treatment for sleep-disordered breathing (SDB) in many otorhinolaryngology (ENT) departments. It effectively reduces AHI and daytime sleepiness by addressing upper airway obstruction. Its precision and reduced recovery time make it a valuable option in the multidisciplinary management of OSA (Vicini et al., 2017; De Vito et al., 2021; Rathesha et al., 2025).

Surgically Assisted Rapid Palatal Expansion (SARPE) and **Mini screw-Assisted Rapid Palatal Expansion (MARPE)** SARPE has shown promise in adults by increasing nasal cavity volume and improving breathing function. MARPE, which does not require osteotomies, has also demonstrated skeletal expansion in young adults and may improve OSA signs and symptoms (Brunetto et al., 2022; Rathesha et al., 2025).

Bariatric Surgery
Bariatric surgery, including procedures such as laparoscopic sleeve gastrectomy and Roux-en-Y gastric bypass, is indicated for patients with severe obesity (BMI $\geq$ 40 kg/m^2) or those with a BMI $\geq$ 35 kg/m^2 and significant comorbidities. These procedures foster weight loss, which can significantly reduce the severity of OSA (Li et al., 2025; Rudolph, 2025).

Effectiveness of Surgical Treatment

The effectiveness of surgical treatment for OSA varies depending on the type of procedure and the patient's anatomical and physiological characteristics. Short-term outcomes often show significant improvements in AHI and other polysomnographic parameters (De Vito et al., 2021). For instance, UPPP and its modifications have demonstrated varying success rates, with BRP and ESP showing the most promising results (Vlad et al., 2023).

Long-term stability and quality of life improvements have been observed in patients undergoing MMA, with reports of high satisfaction rates and sustained reductions in OSA symptoms (Francisco et al., 2025). However, the recurrence of OSA symptoms has been noted in a subset of patients undergoing bariatric surgery, highlighting the need for ongoing management and potential additional interventions (Rudolph, 2025).

In conclusion, surgical intervention plays a crucial role in the management of OSA, particularly for patients with anatomical abnormalities or those who do not tolerate CPAP (Gunel et al., 2025). The choice of surgical procedure should be tailored to the individual patient's needs, considering the risks, benefits, and long-term outcomes of each option.

Alternative Treatments for Obstructive Sleep Apnea

Alternative therapies have been explored to provide effective solutions for individuals who cannot tolerate CPAP or for those with moderate-to-severe OSA. Several promising options, including hypoglossal nerve stimulation (HGNS), orofacial myofunctional therapy (OMT), and other emerging treatments, offer new hope for improved patient outcomes.

Hypoglossal Nerve Stimulation (HGNS)

Hypoglossal nerve stimulation has gained widespread acceptance as an alternative treatment for patients with moderate-to-severe OSA who cannot tolerate CPAP therapy (Gunel et al., 2025) or it is recurrent (Kompelli et al., 2019). HGNS works by stimulating the hypoglossal nerve, causing the tongue to protrude and thereby preventing airway collapse during sleep. Studies have demonstrated that HGNS can reduce the apnea-hypopnea index (AHI) by approximately 70% and significantly improve both subjective and objective outcomes, such as daytime sleepiness, with high patient satisfaction and adherence rates, making it a promising alternative for CPAP-intolerant patients (Henning et al., 2025; Van Loo et al., 2024).

Moreover, HGNS has demonstrated significant clinical efficacy, including reductions in AHI, oxygen desaturation, and improvements in sleep quality (Rathesha et al., 2025). It is particularly beneficial for patients with low BMI and CPAP intolerance, providing substantial relief and better oxygenation (Rathesha et al., 2025). With its proven effectiveness, HGNS is becoming an increasingly popular second-line therapy for OSA (Masqai et al., 2021). The STAR study further supports HGNS as an effective treatment for moderate-to-severe OSA, showing substantial improvements in AHI and overall sleep quality (Rathesha et al., 2025).

Orofacial Myofunctional Therapy (OMT)

Orofacial myofunctional therapy (OMT) has emerged as an adjunctive or standalone therapy for OSA. This treatment involves exercises aimed at improving the strength, tone, and coordination of the tongue and oropharyngeal muscles (Rathesha et al., 2025). OMT has been shown to reduce OSA severity and improve the AHI, making it a valuable tool in managing OSA, particularly for individuals with mild-to-moderate forms of the condition (Gabrieldos et al., 2025; Li et al., 2025; Mediano et al., 2019). Research has demonstrated that a combination of OMT with CPAP therapy can result in significant reductions in AHI and improvement in sleep quality (Rathesha et al., 2025). The effectiveness of OMT in adults with moderate OSA has also been reported, with a notable reduction in neck circumference and OSA severity after a few months of targeted exercises (Lorenzi-Filho et al., 2017).

Cognitive Behavioral Therapy (CBT-I)

Cognitive behavioral therapy for insomnia (CBT-I) has shown promise as an adjunct to positive airway pressure (PAP) therapy in obstructive sleep apnea (OSA) patients, especially those with comorbid insomnia. Studies indicate that combining CBT-I with PAP therapy results in faster improvements in sleep and daytime functioning (Tu et al., 2022). Additionally, initiating CBT-I before CPAP therapy enhances CPAP adherence and reduces insomnia symptoms (Sweetman et al., 2019). Given its effectiveness, CBT-I should be considered for OSA patients with insomnia to optimize treatment outcomes (Sweetman et al., 2017).

Other Emerging Treatments

Several other alternative treatments for OSA have been investigated, offering additional options for patients who do not respond to conventional therapies. One such treatment is the use of cervical collars to extend the neck, which has been shown to improve respiratory indices in patients with moderate OSA, particularly in cases of positional OSA (Delijaj et al., 2025). The use of high-flow nasal cannulas (HFNC) has also been explored for CPAP-intolerant patients, providing a viable solution for those requiring a non-invasive method of improving oxygenation (Wali et al., 2025). Furthermore, intra-oral negative pressure therapy (OPT) has been found to be effective in improving airway patency in OSA patients, offering another promising alternative to CPAP therapy (Lin et al., 2025).

In addition, magnetic systems have been shown to stimulate bony remodeling at the level of the jaw bones, potentially improving skeletal patterns commonly seen in OSA patients. This innovation, along with telemedicine-based diagnostic pathways, holds promise for enhancing patient care and treatment accessibility (Nuncera et al., 2025; Moffa et al., 2025).

Moreover, artificial intelligence (AI) is transforming OSA management by facilitating large-scale screening, automating data analysis, forecasting treatment adherence, and personalizing care. (Rathesha et al., 2025; Lavalle et al., 2025). These advancements significantly enhance

diagnostic and treatment processes, improving patient outcomes and quality of life (Elhaddaoui et al., 2025).

Conclusions

Future research should focus on long-term clinical outcomes, the comparative effectiveness of diagnostic methods, and strategies to enhance patient adherence and treatment precision.

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All authors have read and agreed with the published version of the manuscript.

Funding Statement

This study did not receive external funding.

Informed Consent Statement

Not applicable.

Data Availability Statement

The authors confirm that the data supporting the findings of this study are available within the article's bibliography.

Acknowledgments

Not applicable.

Conflict of Interest Statement

The authors declare no conflicts of interest.

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