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Diagnosis and treatment of Obstructive Sleep Apnoea - A review of surgical methods

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ABSTRACT

Obstructive sleep apnoea (OSA) is a prevalent sleep-related breathing disorder characterized by recurrent collapse of the upper airway and intermittent hypoxia. These are associated with substantial cardiovascular, metabolic, and neurocognitive implications. CPAP remains the standard of care, yet many patients cannot tolerate CPAP, further supporting interest in surgical options. This review summarizes the existing literature on surgical options for OSA, encompassing management of the nose, soft palate, tongue base, craniofacial skeleton, and neuromodulation. We emphasize the importance of diagnostic tools, including polysomnography and drug-induced sleep endoscopy (DISE), to ensure that specific patients are selected for surgical treatment. Present evidence indicates that surgical outcomes are not uniform, although multilevel surgery combined with hypoglossal nerve stimulation is the most consistently effective. Surgical treatment is no longer a generic option in the management of OSA, and future advances will probably develop further hybrid and minimally invasive strategies.

Keywords: obstructive sleep apnoea, hypoglossal nerve stimulation, multilevel surgery, maxillomandibular advancement

1. INTRODUCTION

Obstructive sleep apnoea (OSA) is a prevalent sleep-related breathing disorder, defined by recurrent episodes of partial or complete upper airway collapse during sleep that result in cyclic intermittent hypoxia, disrupted sleep and daytime hypersomnolence (Slowik et al., 2025). The pathophysiology of OSA is complex; it is multietiological and involves both anatomic and neuromuscular factors, including upper airway narrowing, reduced pharyngeal dilator muscle activity, increased ventilatory control instability (loop gain), and a low arousal threshold, leading to collapse during sleep (McNicholas et al., 2023). Central sleep apnoea (CSA), on the other hand, is due to a temporary cessation of central respiratory drive; mixed sleep apnoea (MSA) comprises both obstructive and central events (Thomas et al., 2007). OSA is an important health problem with significant clinical and economic consequences. Epidemiological studies report that OSA affects 9–38% of adults to at least a mild degree, with between 17 and 9% of middle-aged men and women having moderate-to-severe disease (Benjafield et al., 2019). The incidence is proportional to age, obesity, and may also be related to anatomical variations of the upper airway, sex, alcohol intake, and some endocrinopathies, such as hypothyroidism (Abbasi et al., 2021).

Untreated OSA has been linked to various maladies, such as cardiovascular events (hypertension, coronary artery disease, stroke, heart failure), metabolic abnormalities (insulin resistance and type 2 diabetes), as well as neurocognitive deficits (daytime somnolence, poor attention, and mood disorders) (Levy et al., 2015). CPAP (Continuous positive airway pressure) is the gold standard for treating OSA and has been proven effective in preventing upper airway collapse during sleep. Unfortunately, a substantial percentage of patients are intolerant of CPAP and do not use this therapy due to discomfort, claustrophobia, or mask-related issues, which results in poor compliance and ineffective treatment (Weaver and Sawyer, 2010). As a result, surgery has come to serve as an effective substitute or complement for certain patients. Uvulopalatopharyngoplasty, maxillomandibular advancement, tongue base reduction, and hypoglossal nerve stimulation are performed with the same purpose of increasing or improving stability of the upper airway and airflow (Tanna et al., 2016). With the rising prevalence of OSA and inadequacy of traditional treatments, a review of these surgical options is indicated.

The objective of this study is to review the literature on the indications, effectiveness, and safety of surgical treatment options for OSA to delineate more precisely the appropriate candidates for these modalities. Another important aspect is to provide an overview of very recent challenges (CPAP intolerance and multimorbidity), highlighting, with the emphasis they deserve, the clinical relevance of surgical treatment alternatives.

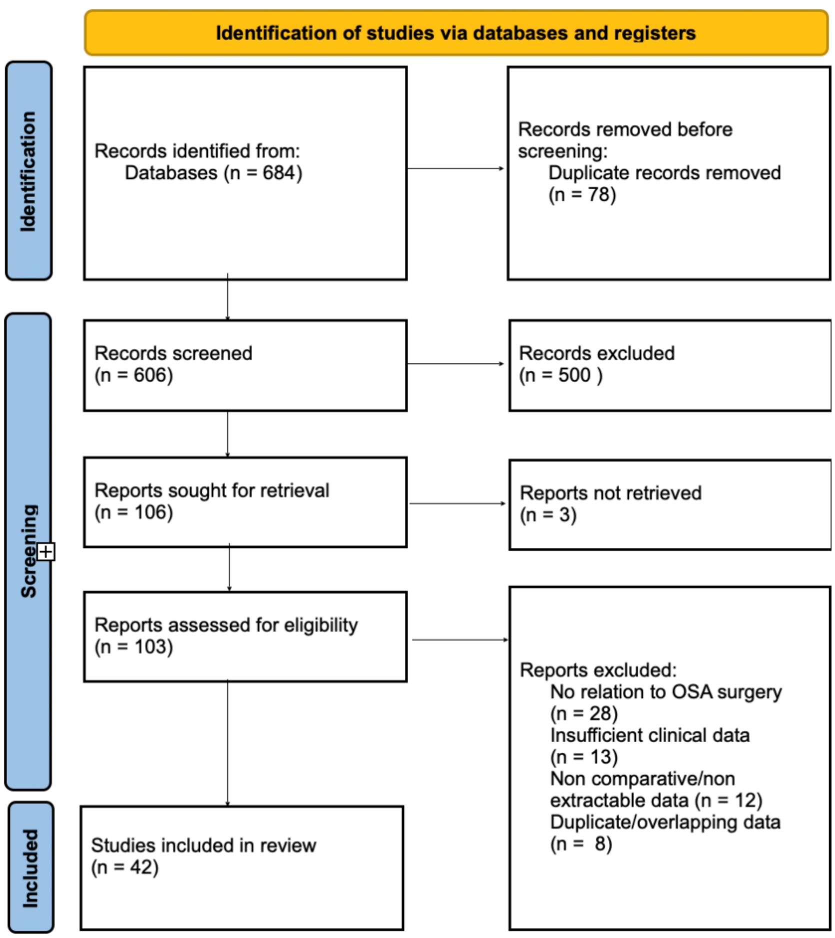

Figure 1. PRISMA flow chart

2. REVIEW METHODS

This article provides an overview of the available evidence on surgical treatment for OSA. We systematically searched PubMed, Scopus, Web of Science, and Google Scholar to identify studies until January 2025. Search terms combined the keywords OSA with surgical treatment, for example, uvulopalatopharyngoplasty (UPPP), maxillomandibular advancement, tongue-base surgery, hypoglossal nerve stimulation, and multilevel. Only adult patients diagnosed with OSA by validated sleep testing and reporting extractable clinical outcomes in peer-reviewed studies were included. We did not include studies with pediatric-only populations, on acute perioperative physiology (such as those using transfusion or non-human models), and/or those without outcome data. The PRISMA flowchart (Figure 1) describes the entire process of study selection.

3. RESULTS & DISCUSSION

Diagnosis

The gold standard for diagnosing OSA is polysomnography (PSG). It measures several physiological channels: EEG, EOG, EMG, airflow, respiratory effort, and oxygen saturation. All of these variables enable the specific determination of apneas, hypopneas, and arousals. PSG assesses sleep architecture and the presence of respiratory abnormalities, and is especially recommended when comorbidities are present, when complex sleep apnea is suspected, or when an earlier evaluation was not conclusive. In addition to its role in diagnostics, PSG permits quantification of sleep efficiency, which may influence treatment selection and prognosis. In addition, digital signal processing and automated event scoring have brought about advances in standardization and inter-laboratory reproducibility that support longitudinal follow-up studies and multicenter comparisons (Kapur et al., 2017; Caples et al., 2021).

In adult patients without complicating conditions and with a high pre-test probability of moderate-to-severe OSA, home sleep apnea testing (HSAT) is an established, readily available alternative. Datasets collected by HSAT devices tend to have fewer parameters (airflow, respiratory effort, and oximetry). Nevertheless, various studies show that they are accurate in diagnosing properly selected patients (Ramar et al., 2021). Although it is advantageous in terms of cost and convenience, HSAT lacks electroencephalographic channels for sleep staging and may underestimate disease severity. What is also interesting to see is that you are not supposed to use it in people with severe cardiopulmonary or neuromuscular disease, and if central sleep apnea is suspected as well.

Newer generations of HSAT equipment now include cloud-based data transfer and automated scoring algorithms, which have improved the efficiency of collecting patient information and the diagnostic yield. However, clinician supervision and prudent patient selection are essential to reduce false negatives and allow proper result interpretation (Hynes and Mansfield, 2024). Several relevant indices can be calculated from PSG and HSAT, namely, apnea–hypopnea index (AHI), oxygen desaturation index (ODI), respiratory disturbance index (RDI), as well as oxygen saturation values (SpO_2). The AHI is the number of apneas/hypopneas per hour of sleep and is still the main severity measurement. Mild (5–14 events/h), moderate (15–29 events/h), and severe (≥ 30 events/h) levels of OSA are defined by AHI (Foldvary-Schaefer and Waters, 2017).

The ODI is an index of desaturations/hour and serves as a strong predictor of hypoxic burden, whereas the RDI includes respiratory-effort–related arousals (RERAs), rendering the device more sensitive to mild derangements. A 24-hour SpO_2 recording provides important information on the severity and duration of nocturnal hypoxemia, variables that have been accepted as prognostically relevant beyond AHI. Furthermore, recent evidence indicates that cumulative hypoxic burden provides better risk stratification for CV and metabolic diseases than traditional AHI-based classification, underscoring the need to include SpO_2-derived parameters in the screening of these emerging disorders (Azarbarzin et al., 2019). Clinical assessment remains a critical diagnostic factor. Questionnaires such as the Epworth Sleepiness Scale (ESS), STOP-BANG, and Berlin Questionnaire help identify those at increased risk and estimate daytime sleepiness. The STOP-BANG score (snoring, tiredness during the day, observed apneas while sleeping, high blood pressure and BMI, age over 50 years, neck circumference, and male gender) has been highly sensitive for moderate-to-severe OSA in surgical and preoperatively patients. These questionnaires are useful in low-resource settings and in primary care when formal sleep testing may not be readily available. The use of a combination of screening tools and clinician judgment results in more accurate diagnoses and aids in prioritizing patients for further evaluation, especially in surgical or cardiovascular clinics with high OSA prevalence (Chen et al., 2021; Nagappa et al., 2015). Anatomic evaluation is another pillar of assessment. This bedside assessment of upper airway narrowing and collapsibility, using the Mallampati classification and Friedman staging, supplemented by BMI and neck circumference, has been useful. Neck circumference and BMI are strong predictors of pharyngeal fat and airway collapsibility.

Anatomical phenotyping is particularly pertinent for identifying OSA phenotypes that may benefit from specific therapies, namely tonsillectomy, tongue-base reduction, and skeletal surgery. The increasing application of 3D surface imaging and digital anthropometry offers new potential for an objective assessment of craniofacial- and soft-tissue-based features related to airway obstruction (Yayan and Rasche, 2024). Accurate localization of upper-airway obstruction is crucial for surgical design. ATIC and Müller's maneuver are static studies, while DISE is a dynamic method of visualizing the collapse of the airway under sedation that mimics sleep. The VOTE (Velum, Oropharynx, Tongue base, and Epiglottis) classification allows a standardized report to be generated and has been proven to increase inter-observer agreement and the surgical approach.

Furthermore, the development of automated DISE analysis and image recognition is increasing the objectivity and reproducibility of airway anatomy analysis. Besides determining surgical candidacy, these findings support multi-modal treatment management such as positional therapy, oral appliance construction, and upper-airway stimulation (da Cunha Viana et al., 2017; Hanif et al., 2023). Radiologic modalities, including CT, MRI, and 3D cephalometry, can provide quantitative data on airway volume, the distribution of soft tissues, and relationships within the craniofacial skeleton. Contemporary 3D MRIs and dynamic imaging now offer sufficient resolution to visualize specific patterns of collapse during simulated sleep, which may enable personalized surgical management. Imaging is not only useful for planning surgery but also for investigating OSA physiopathology, with images showing differences in airway compliance and parapharyngeal fat distribution amongst phenotypes.

Advances in low-dose CT protocols and ultrafast MRI sequences have facilitated these techniques, making it practical to examine airway remodeling before and after surgery with reduced risk and improved accuracy (Chen et al., 2016). Surgical eligibility should ultimately be based on an overall assessment of disease severity, anatomic obstruction, and tolerance to non-surgical treatment (CPAP or oral appliance). Indications are moderate to severe OSA with a surgically correctable anatomic deformity and CPAP intolerance. Contraindications include uncontrolled systemic disease, morbid obesity that is above the limits for surgical safety, or no surgically correctable obstruction. Recent functional and anatomic staging-based frameworks have advanced patient selection and predicted surgical success rates (Lee and Sundar, 2021).

Treatment

Nasal surgery

Nasal surgery, such as septoplasty, conchoplasty, and FESS, primarily aims to improve nasal airflow rather than cure OSA; these procedures aim to reduce resistance rather than treat OSA. Its clinical utility is in patients with structural nasal obstruction who cannot tolerate CPAP. In these patients, surgical management of nasal pathology was shown to improve CPAP comfort, reduce the therapeutic pressure required, and increase nightly hours of use. A pooled analysis by Camacho et al., (2015), which comprised 18 studies and 279 patients, reported that nasal surgery resulted in a significant decrease in mean therapeutic CPAP pressures from 11.6 ± 2.2 cm H_2O to 9.5 ± 2.0 cm H_2O (50% AHI reduction in ~53% of severe OSA patients and mean AHI dropping from 41.3 to 17.4 events/h at six months (Despeghel et al., 2017). Office-based multilevel RFA for mild/moderate OSA has shown substantial decreases in AHI (from 19.7 to 9.9) and ESS (from 11.2 to 6.0), with minimal morbidity (Herman et al., 2023). Outcomes from an RCT comparing tonsillectomy with modified UPPP in individuals with tonsillar hypertrophy were similar between the two groups (mUPPP: AHI 51.0–28.0; TE: AHI 56.9–24.7), suggesting that anatomical selection is more important than technique (Sundman et al., 2022). Complication profiles are specific to approach: LAUP may be associated with persistent pain, scarring, and occasionally OSA progression, while surgical palatal procedures have the possibility of bleeding, transient dysphagia and uncommonly long-term voice changes, though newer iterations generally report low rates of severe morbidity.

Procedures of the base of the tongue and other procedures of the oropharyngeal wall

Operative approaches to the tongue base and lower airway structures have shifted the emphasis toward manipulation of anatomic factors that contribute to OSA by decreasing the volume of obstruction or altering skeletal and/or muscular relationships. Midline glossectomy using conventional techniques, laser ablation, or coblation is intended to reduce the bulk of the tongue base and to size the retrolingual airway. Recent series describe statistically significant but only moderate benefits. Coblation midline glossectomy alone was used to treat mild and moderate OSA, and the mean AHI decreased from 34.9 ± 20.9 (at baseline) to 25.8 ± 17.6 posttreatment, with approximately half of this population adding clinical success and improvements in ESS and desaturations (Süslü et al., 2021).

Despite the fact that it has a favourable safety profile with less morbidity compared with other more invasive modalities, final results are largely related to both BMI and the degree of preoperative tongue base hypertrophy. In contrast, TORS is a more accurate and reproducible technique for reducing the tongue base, with the potential to resect deep retrolingual tissue in a controlled manner. A meta-analysis showed a significant decrease in AHI from 44.3 ± 22.4 to 17.8 ± 16.5, with surgical success and cure rates of 68.4% and 23.8%, respectively. TORS additionally improves minimum SaO_2 and subjective sleepiness scores, but success depends on appropriate patient selection (Miller et al., 2017). In repositioning procedures such as genioglossus advancement (GA), the anteroposterior advancement of the genioglossus bony attachment alters tongue-base dynamics. Dramatic improvements, however, are suggested by recent studies (although with a small sample size). One recent series in 2017 described a decrease in the mean AHI from ca. 36 to 4.3 points after adapted GA (Vargo et al., 2017).

Hyoid suspension (HS), which is designed to pull the hyoid forward and inferiorly to dilate the hypopharyngeal airway, has limited success as a single procedure but adds incremental value in multilevel approaches. Modern reviews report a success rate of 18%–30% on average when the procedure is performed as an exclusive intervention (Spyropoulou et al., 2022). Together, these interventions translate into significant reductions in AHI, increased oxygenation, and stabilization of the upper airway. However, heterogeneity of results among studies calls for patient-centered surgical planning, comprehensive preoperative evaluation (e.g., DISE, cephalometrics), and realistic expectations, as full remission is still a rare outcome with conflicting evidence that multilevel approaches are more efficacious than isolated tongue base surgery.

Contemporary Evidence on Multilevel, Skeletal, and Neuromodulatory Surgery

Multilevel surgery, combining uvulopalatopharyngoplasty (UPPP), genioglossus advancement (GA), and hyoid suspension, has been postulated to be superior for managing heterogeneous or multilevel airway collapse in patients with moderate-to-severe OSA. Unanswered questions evidence shows that combined palatal–lingual–hypopharyngeal surgery is more effective than unilevel surgery, particularly if it is selected on the basis of DISE. Single-stage UPPP+GA+hyoid suspension achieves a 50–70% decrease in AHI and subjectively meaningful improvements in ESS and nocturnal oximetry (Bosco et al., 2021). Comparative studies also indicate that single level procedures offer limited reductions in AHI and low treatment success rates compared to multilevel procedures for patients with multi-level collapse, where isolated approaches result in a mere 12–20 events/hour reduction of AHI, whilst multilevel surgery achieves a more consistent 28–40 events/hour decrease at very low complication rates in experienced centres (Bosco et al., 2021). Along this spectrum, MMA remains the most potent surgical treatment, yielding success rates greater than 80% and cure rates of 40–45%, with strong mean postoperative AHI reductions of >50 events/hour (Giralt-Hernando et al., 2019). Other long-term follow-ups also demonstrate sustained improvement in sleep-related breathing. Although MMA shows an extraordinary effectiveness, there are significant drawbacks to this technique: expenses, longer recovery time, facial soft tissue changes in some cases, and the need for orthodontics, which can prolong planning (Trindade et al., 2023).

A more minimally invasive option, hypoglossal nerve stimulation (HNS) provides targeted muomechanical neuromodulation of tongue protrusor muscles and has been shown to have durable 50%–70% AHI reduction at long-term follow-up with good adherence and improvements in quality of life (Wray et al., 2016; Dedhia et al., 2015). It is noteworthy that this approach has strict eligibility criteria, such as BMI <32–35 kg/m² and no complete concentric palatal collapse, but with documented CPAP intolerance. Palatal implants offer minimally invasive treatment with modest improvement in snoring and mild OSA, but systematic reviews report poor efficacy for moderate-severe OSA, best results among non-obese patients, and among those with isolated palatal vibration (Khasawneh et al., 2021).

Table 1. Summary of surgical treatment options for obstructive sleep apnea, including representative procedures, therapeutic effects, and key clinical considerations

Category	Examples	Effect	Key point
Nasal surgery	Septoplasty, FESS	↓ resistance, ↓ CPAP pressure	Improves CPAP tolerance, not curative
Soft tissue surgery	UPPP, RFA, glossectomy	Moderate ↓ AHI	Outcome depends on anatomy
Multilevel surgery	UPPP + GA + HS	↓ AHI ~50–70%	More effective than single-level
Skeletal surgery	MMA	>80% success	Most effective, but invasive
Neuromodulation	HNS	↓ AHI ~50–70%	For selected CPAP-intolerant patients

In deep pharyngeal sites, robot-assisted upper-airway surgery provides better exposure and greater accuracy in achieving tumour resection control, while simultaneously minimizing tissue damage and achieving satisfactory physiological outcomes in patients, compared with non-robotic approaches (Rangabashyam et al., 2016). In the future, there will be a trend toward individualized, minimally invasive approaches in the reconstructive field, including hybrid options combining soft-tissue procedures with skeletal procedures, as well as neuromodulatory treatments. Promising techniques like image-guided radiofrequency remodelling, endoscopic lateral wall stabilization, and second-generation nerve stimulators seek to enhance specificity and reduce morbidity, while DISE phenotyping or computational models are likely to better select patients and plan operations (Spyropoulou et al., 2022). The principal surgical treatment modalities for OSA and their clinical outcomes are summarized in Table 1.

4. CONCLUSION

Despite its well-established prevalence and clinical importance, OSA remains a disorder with a complex, multifactorial pathophysiology. The diagnosis is best made using polysomnography, validated home sleep testing, and comprehensive functional assessment. There is increasingly compelling evidence that universal CPAP treatment loses its efficacy with mandibular advancement therapy, raising surgical OSA management as a critical part in an individual approach. Modern surgical interventions comprise nasal, palatal, tongue-base, skeletal, and neuromodulatory techniques targeted at specific anatomic factors contributing to upper airway collapse. To date, the majority of publications show that while individual operations such as tonsillectomy or partial glossectomy may offer substantial benefit in specific patients, multilevel surgery directed by careful preoperative assessment, including DISE and advanced imaging, has been shown to produce more consistent reductions in AHI, improved measures of oxygen exchange, and better symptom relief. Maxillomandibular advancement remains the most effective anatomic intervention, while hypoglossal nerve stimulation is a promising novel treatment for select CPAP nonresponders who are intolerant of CPAP.

Interventional approaches have also established themselves, with the advantages of lower morbidity and better patient compliance. In place of this progress, however, no single surgical method provides the ultimate cure. Favorable outcomes rely on individualized treatment planning based on clear patient phenotypes, anatomical staging, and assessment of multimorbidity. The future may favor hybrid strategies that include skin remodeling in coordination with skeletal repositioning and neuromodulation, complemented by artificial intelligence-assisted diagnostics and improved predictive tools to better select patients for surgery. In conclusion, SE is an important, evidence-based adjunct to contemporary OSA therapy. Its function will expand as PM principles oversee, driving durable improvements.

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Conflict of interest

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Data and materials availability

All data associated with this study will be available based on the reasonable request to corresponding author.

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