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Surgical Therapy of Obstructive Sleep Apnea: A Review

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Abstract Obstructive sleep apnea (OSA) is a disease characterized by intermittent and repetitive narrowing of the airway during sleep. Surgical therapies for the treatment of OSA aim to improve airway patency by addressing selected site(s) of obstruction. Because several areas may each be responsible for the narrowing, different surgical modalities have also been developed. In this review, we give an overview of surgery for each of potential obstruction site(s). As a consequence of the multi-factorial and heterogeneous etiology of OSA, surgical therapies need to be selected and performed specifically for each patient, as there is no perfect surgery that will fit all patients. As with any other treatment modalities for OSA, surgical therapies have variable efficacy, but are a very important tool on OSA management in selected patients and have been shown effectiveness in decreasing the morbidity and mortality associated with the disease.

Keywords Sleep apnea · Obstructive sleep apnea · OSA · Surgery · Treatment

Introduction

Obstructive sleep apnea (OSA) is a syndrome characterized by intermittent and repetitive upper airway collapse or narrowing during sleep [1]. Repetitive closure of the upper airway results in sleep fragmentation, hypoxemia, hypercapnia, and increased sympathetic nervous system activation, all of which lead to symptoms, such as excessive daytime sleepiness and cognitive impairment. In addition, OSA increases an individual's risk for developing cardiovascular disease, endocrinologic abnormalities, and even early mortality [2].

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The gold standard for diagnosis is a polysomnogram (PSG) or overnight sleep study. In regard to OSA, a PSG calculates the number of obstructive airway events per hour of sleep, known as the apnea-hypopnea index (AHI). An AHI < 5 is considered normal. An AHI between 5 and 15 is mild OSA; 15 to 30 AHI is moderate OSA, and an AHI > 30 indicates severe OSA.

Continuous positive airway pressure (CPAP) device is currently considered to be the first-line treatment for OSA in adults [3]. When used properly, CPAP treatment is efficacious at reducing both subjective symptoms of OSA and cardiovascular risk [4, 5]. However, CPAP efficacy is limited by highly variable patient compliance to therapy. In the literature, the reported adherence to CPAP ranges from 30 to 70 % [3, 6]. Thus, a significant number of patients ultimately abandon CPAP therapy.

For patients who are intolerant to CPAP, physicians must consider other treatment modalities. Alternative treatment options include a multitude of options, and among them is surgery.

Surgery may be used as a primary treatment option in select patients who have identifiable anatomical problems (e.g., enlarged tonsils) or it may be used as a "salvage" treatment option for patients who are not compliant with CPAP. Despite a variable cure rate, surgery has been shown to routinely decrease OSA severity and increase subjective quality of life [7, 8].

The anatomical cause of OSA is generally heterogeneous, with multiple potential levels of airway obstruction; therefore, many different surgical procedures have been developed for the treatment of OSA [9, 10].

Presurgical Evaluation

Although PSG is the gold standard for the diagnosis of OSA, it does not provide information in regard to the location of obstruction. A pre-surgical patient evaluation includes a physical examination and a flexible fiberoptic nasopharyngoscopy to evaluate the upper airway to identify potential sites of collapse. Several other diagnostic modalities have showed some value to supplement a physical examination, including lateral cephalogram, 3-dimensional cone beam computed tomographic scan, sleep endoscopy, or cine-magnetic resonance imaging (MRI) [11–13]. The last 2 have been shown some promise because they evaluate static and dynamic aspects of the upper airway while asleep or in a sleep-like state.

Sleep endoscopy involves only mild sedation with a hypnotic drug, such as midazolam or propofol. A flexible fiberoptic endoscope is then introduced nasally and oropharyngeal and hypopharyngeal areas are observed for collapse [12]. This examination is advantageous because it of the dynamics of being performed while the patient is in a sleep state, and therefore it reproduces what may be occurring while the patient is asleep. Drug induced sleep endoscopy has been shown to be a valid assessment of the upper airway, with moderate-to-substantial test-retest reliability and moderate-to-substantial inter-rater reliability. It allows the evaluation of the airway in a situation as close to sleep as possible [14, 15]. Sleep MRI has the advantage of evaluating the airway without the presence of instruments within its lumen, and in a stage of natural sleep, allowing a dynamic characterization of the levels of obstruction, as it captures real-time images that create a “movie.” It has shown very high coefficients of intra- and inter-rater reliability for the determination of presence or absence of obstruction [16]. Sleep MRI is still being investigated as a diagnostic tool, and further methodological improvement will be necessary before considering its widespread use.

Both examinations are commonly used to evaluate surgical failures to identify residual sites of obstruction, or are used in complex cases in which the history and/or PSG do not appear to match the patient’s symptoms. These tools should be used to help inform our clinical/surgical decision-making to better counsel patients.

As previously mentioned, every patient should be offered a CPAP trial prior to surgery. In addition to being the most conservative approach, it may be helpful as a noninvasive means to determine the likelihood of improvement of symptoms after surgery, and to minimize the chance of perioperative complications [17]. In addition, patient counseling should also include behavioral modifications, such as weight loss, diet, physical exercise, positional therapy, and avoidance of sedatives, regardless of the treatment option chosen [18].

Surgical treatment can be considered once a patient has failed CPAP therapy, despite counseling and correction of common CPAP issues. An exception is when the patient has an identifiable physical abnormality, such as enlarged tonsils or a severely deviated septum. A key to effective surgical therapy involves determining sites of airway obstruction or narrowing, interpreting a patient’s PSG data, and understanding which surgical procedures are appropriate for each patient. Synthesizing all the data helps develop a specific plan, as each patient is unique. Equally important is recognizing that not every patient will be a good surgical candidate due to the patient’s sleep physiology or anatomy or comorbidities. Therefore, it is paramount to have a good understanding sleep medicine, sleep surgery, and general medicine.

Surgery should only be undertaken after comprehensive patient counseling has occurred. Counseling includes discussion of potential sites of obstruction, and surgical, as well as nonsurgical, treatment options. If additional diagnostic testing is recommended, the purpose and goals of these additional tests should be discussed with the patient. Even if surgery is being considered as the primary treatment option, CPAP and other conservative therapies should still be considered.

Bearing in mind that OSA is a disease with severe complications abiding considerable perioperative risk, certain measures are necessary when considering surgical treatment. Complications include higher intubation rates, hypercapnia, oxygen desaturation, cardiac arrhythmias, necessity of intensive care unit transfer and others. The anesthetic effect can linger for several days after the surgery, and therefore caution with opioid agents is extremely important. Considering these patients have suboptimal airways and surgery is performed in the airway, monitoring for respiratory events and oxygen saturation is advised, preferably in the intensive care unit. The use of CPAP therapy is recommended both preoperatively and postoperatively [19].

Objectives

The main objective of OSA surgery is to improve or eliminate the airway collapse that occurs during sleep while preserving the normal function of the upper airway and related structures, such as speech and swallowing. In the literature, surgical success has been traditionally defined as a reduction of the AHI by 50 % and AHI < 20 after surgery. The criteria for a treatment cure are defined as an AHI < 5 after treatment [9, 10, 20].

Other goals of surgery include normalization of sleep quality, improvement of the AHI and oxygen saturation levels [18]. A bed partner’s complaints of snoring should also be remembered as an important outcome [21].

A surgical treatment plan is made according to the site(s) of obstruction. Surgery can consist of either soft tissue removal or a skeletal modification [9] (see Table 1).

Table 1 Treatment modalities according to anatomical location[a]

Treatment modality		
Anatomic location		Surgical procedure
Nasal cavity	Soft tissue	Polypectomy, ablation of turbinate
	Skeletal	Septoplasty
Nasopharynx		Adenoidectomy
Oropharynx	Soft tissue	Tonsillectomy, UPPP, LAUP
	Skeletal	Rapid maxillary expansion
Hypopharynx	Soft tissue	Midline glossectomy, tongue base reduction
	Skeletal	Mandibular advancement, genioglossal advancement, hyoid myotomy suspension
Oro and hypophanrynx	Skeletal	Maxillomandibular advancement
Bypass of the airway		Tracheotomy

LAUP uvulopalatoplasty; *UPPP* uvulopalatopharyngoplasty

[a]Adapted and modified from Sher, AE. Upper airway surgery for obstructive sleep apnea. Sleep Med Rev 2002;6:195–212

Although CPAP opens the whole airway, surgery aims at specific areas. Therefore, many different surgical techniques have been developed to treat OSA. These surgeries are used to modify the various sites of obstruction. If multiple levels of obstruction exist, a combination of surgery modalities is indicated. Therefore, the surgeon should be familiar with each procedure to determine the appropriate surgical plan. Patient counseling in regard to success rates and potential complications of each modality of surgery is recommended [18, 22].

Types of Surgery

Nasal Surgery

In those patients with nasal obstruction and Sleep Disordered Breathing, oral breathing may also impose instability in respiration and sleep. In 1 study of sleep in normal subjects, upper airway resistance was shown to be lower with imposed nasal breathing than with imposed oral breathing, in contrast to the supine and upright awake states, in which nasal resistance is higher than oral resistance. In normal sleeping subjects, nasal breathing is expected to be the preferred route, unless it is impaired and associated with increased work of breathing or destabilized ventilation, in which case a switch to the oral route may be seen [23, 24].

Surgery of the nasal cavity includes correction of a deviated septum, inferior turbinate reduction, alar valve reconstruction, as well as sinus surgery, if sinus disease is present [10]. The goal of these surgeries is to improve nasal airflow by correcting the obstructing structures, such as a deviated septum or enlarged turbinates. Thus far, the literature has shown that nasal surgery alone rarely successfully treats OSA. However, studies do indicate that nasal surgery does improve sleep quality. It can also help improve CPAP adherence and compliance, by reducing the necessary pressure and increasing hours of use [25].

Surgeries of the Oropharynx

Patients with OSA typically have redundant tissue of the oropharynx. Tissue tends to be more flaccid and elongated. Oropharyngeal surgery is aimed to decrease the tissue redundancy and help stiffen flaccid tissues.

Uvulopalatopharyngoplasty (UPPP) was first described by Fujita et al. [26]. Presently, UPPP is the most widely performed surgery for the treatment of OSA in adults [10, 27]. Success rates for isolated UPPP in the treatment of OSA are highly variable, depending on the size of the tonsils and the patient's body mass index [28]. Several variations of the technique have been proposed with similar outcomes [29]. UPPP has been also shown to be useful to lower CPAP pressure requirements, improving CPAP compliance in certain patients [30].

Several procedures have been developed to help address patients with primary snoring, such as laser-assisted uvulopalatoplasty, radiofrequency palate ablation, and pillar implants. However, these procedures have limited use in treating OSA.

In laser-assisted uvulopalatoplasty, a carbon dioxide laser is used to make small mucosal cuts along the lateral aspect of the soft palate. This procedure has a high success in reducing snoring (approximately 90 %), but is not recommended for the treatment of OSA, because of unpredictable results and even worsening OSA [31, 32].

Radiofrequency ablation of the palate induces submucosal scarring of the soft palate, which helps stiffen the palate. This procedure has been shown to improve snoring, but evidence for treatment of OSA is still lacking [33, 34]. Pillar palatal implants is a minimally invasive procedure based on the insertion of polyester implants in the soft palate, inducing local stiffening. It improves snoring and has been used to treat mild OSA [35].

Surgeries of the Tongue

Another common area of upper airway collapse occurs in the retrolingual area. Sleep apneics can have more fat deposits in their tongues leading to a larger base of tongue size [36]. Lingual tonsil hypertrophy may also be present. The genioglossus muscle is the primary muscle used in airway dilation. Studies have shown that the genioglossus muscle tone in sleep apneics is altered in comparison to normals during sleep [37].

Tongue procedures consist of either tongue reduction procedures or genioglossus muscle suspension procedures. Overall, all tongue procedures improve symptoms of daytime sleepiness and quality of life [10].

Posterior midline glossectomy consists of surgical removal of the central portion of the tongue base. The success rate is variable, ranging from 25 to 83 % [38].

Radiofrequency ablation of the tongue uses radio waves with low temperature energy to coagulate tissues without harming surrounding tissues. It is successful at improving snoring, but only has a surgical success rate of approximately 36 % in regard to OSA [39].

In tongue suspension techniques, nonabsorbent sutures are passed from the anterior neck to the tongue base. The sutures are then anchored to the mandible. This pulls the tongue base forward and prevents collapse during sleep. The success rate is approximately 33 % [6].

In the genioglossus advancement, a parasagittal mandibular osteotomy is made around the genio tubercle. The genioglossus muscle attaches to the genio tubercle and is pulled anteriorly. The success rate can vary from 39 to 78 % [38, 40].

Hyoid suspension can also be used to improve retrolingual space. Advancement of the hyoid advances the epiglottis anteriorly. There is variable advancement of the tongue base, with variable surgical results. This procedure is usually performed as an adjunctive surgery for the treatment of OSA [41].

Craniofacial Surgery

Maxillomandibular advancement (MMA) is performed by creating osteotomies of the maxilla and mandible. The inferior portion of the maxilla/hard palate and the anterior mandible can then be advanced forward. Advancement of the facial skeleton also pulls the attached soft tissues forward (the soft palate is attached to the hard palate and the genioglossus muscles and suprahyoid muscles are attached to the mandible). Tension is also placed along the entire pharynx, which widens the entire pharyngeal space [42].

MMA provides a high percentage of surgical success (86–90 %), even in the absence of skeletal facial deficiency in the horizontal plane. Several studies have shown that a MMA is equal in effectiveness to the nasal CPAP. MMA is the modality of surgery with the highest surgical efficacy and cure rate (43 %) [29, 43].

Although there are changes in facial appearance, Li et al. [44] found that the majority of patients felt that these changes improved their facial appearance.

Typically, a MMA is reserved as the last phase of surgical treatment, but it can also be indicated as initial surgical therapy in selected cases, avoiding the need of multiple surgeries [45].

Tracheostomy

Because a tracheostomy bypasses the upper airway, it is the surgical procedure that more effectively cures OSA [46]. However, patients with cardiopulmonary concomitant disorders, such as chronic obstructive pulmonary disease, congestive heart failure, and obesity with hypoventilation may have residual disease [47].

A permanent tracheostomy tube requires daily maintenance and therefore should be done only in highly selected patients. A temporary tracheostomy can be placed in high-risk patients prior to other airway surgeries as a prophylactic measure.

Weight Loss by Bariatric Surgery

OSA is present in at least 45 % of bariatric patients [48]. Even mild-to-moderate weight loss can improve OSA severity and sleepiness, therefore weight loss should be encouraged for all OSA patients who are overweight [10, 27]. Bariatric surgery is the preferred modality for weight reduction for morbidly obese patients who have failed conservative treatments [49].

In a study of 101 prospective patients that underwent bariatric surgery, Haines et al. [48] showed that surgically induced weight loss alone was able to decrease mean AHI from 51±4 (preoperatively) to 15±2 (postoperatively). Bariatric surgery may be considered an adjunctive treatment of OSA in obese patients. However, the remission rate of OSA after bariatric surgery can be as high as 40 % [22].

Multi-Level Surgery and Staged Surgery

It is now generally accepted that OSA commonly results from narrowing at multiple areas of the upper airway, including soft palate, lateral pharyngeal walls, and tongue base [50]. Rarely is OSA caused by a single isolated site of obstruction.

Hence, a combination of procedures to address airway obstruction at multiple levels may improve success compared to single-site therapy [7, 8, 51, 52]. For example, a nasal procedure may be performed in combination with an oropharyngeal procedure.

Staged surgery protocols have been developed to address multilevel airway abnormalities that contribute to OSA. Generally, procedures that carry less severe risks and potential complications are performed initially. The Stanford group protocol reports a staged surgical success rate of

75 % in patients with mild-to-moderate OSA and 40 % in patients with severe OSA in phase I (palatal surgery alone or in combination with GA) to 95 % in phase II or facial skeletal surgery [53]. In some cases when soft tissue abnormalities are not considered to play a significant role, maxillomandibular advancement can be considered as the initial therapeutic option [45].

Sleep Apnea Surgery in Children

Although exact diagnostic definition is still a matter of debate, it is a consensus that in children a more strict criteria should be used and for some experts, an AHI > 1 is diagnostic of OSA [54]. Early recognition and treatment of OSA in children is essential because airway obstruction in children can lead to behavioral issues, poor school performance, and impaired maxillomandibular growth (leading to alterations in craniofacial structure that can potentially worsen OSA in adulthood) [55].

Surgery in children has a different role than in adults. Because the most common cause of OSA in children is adenotonsillar hypertrophy, adenotonsillectomy, 1 of the most common surgical procedures in children, is considered the first-line therapy for children with OSA [56]. Adenotonsillectomy, is curative in approximately 80 % of pediatric cases of pediatric OSA [57]. Other factors associated with pediatric OSA are craniofacial or neuromuscular abnormalities (Down syndrome, Crouzon and Apert syndromes, Pierre-Robin sequence, cerebral palsy, muscular dystrophy, and others) and obesity. In these cases, surgery is performed to avoid tracheostomy, to improve Respiratory Disturbance Index/AHI and to decrease desaturation levels [56–58].

Rapid maxillary expansion is an orthodontic procedure used to treat transverse maxillary deficiency, by expanding the mid-palatal suture (widening both the palate and the nose). This procedure has been shown to improve AHI in children with OSA, and it also improves snoring, excessive daytime sleepiness, and behavioral problems [59, 60]. It can be performed from ages 5 to 11 [55].

Orthognatic surgery, such as distraction osteogenesis (DO) and MMA are usually performed in older children [55].

DO of the maxilla or the mandible results from gradual distraction with subsequent ossification and lengthening of the bone. Mandibular DO in children with genetic craniofacial abnormalities can improve OSA. [61]

Discussion

A commonly used argument against surgery, as a satisfying treatment for OSA, is that is lacks high level scientific data proving its results. Randomized controlled trials (RCT) are considered the highest level of evidence, but they can often pose methodological challenges, particularly in the field of surgery [29, 62, 63]. For example, it is difficult to justify performing placebo/sham surgical procedures on patients undergoing a general anesthetic. Thus, it is important to recognize the value of non-RCT in evaluating surgical interventions when the implementation of RCTs is impractical or unethical [62, 63].

The surgical success rate for OSA is variable, likely because OSA is not a simple disease. OSA is a heterogeneous syndrome that can have many causes and factors contributing to it at the same time. Differing levels of obstruction, patient characteristics (such as body mass index and age) play an important role in defining which type of surgery to perform. No one surgery should be used indiscriminately to treat all patients. Instead, each patient needs a tailored-made plan for their specific problem. The surgeon's job is to discern if patients will benefit from a surgery and to determine which procedure(s) is most appropriate.

Data suggests that only 25 % of patients present with a uni-level obstruction, whereas 75 % had multi-level obstruction sites [52]. Evidence has shown that single-site surgery has a poor success rate when multilevel obstruction is present. By combining surgical treatment modalities to address multiple levels of obstruction, the success rates can reach as high as 95 % in staged surgical protocols [53].

Sleep disordered breathing is associated with increased mortality and high cardiovascular risk, and therefore should be treated [5]. Leaving patients who cannot use first-line therapy (CPAP) without any treatment option does not seem to be in accordance with good medical practice. Although surgical therapy does not always cure OSA, it does provide significant benefits. Surgery improves disease severity, reduces early mortality risk and cardiovascular risk [64]. Studies have shown improvement in reaction time, quality of life, and motor vehicle crash risk [22, 65].

CPAP is considered to be the first-line treatment of OSA. However, CPAP can only be considered effective if the device is actually used by the patient. Many patients reject CPAP due to various issues. Treatment efficacy is not always the same as treatment effectiveness. Efficacy is the effect a treatment has under ideal conditions. Effectiveness is the effect of a treatment in everyday life. CPAP is highly efficacious, but has variable effectiveness. It can be argued that effectiveness is more important than efficacy to clinical practice. If a patient does not wear the device, even if it has a high efficacy, it will have low effectiveness [66]. Although surgery may have variable efficacy, it is obviously not affected by compliance.

Another argument against surgery is that it rarely provides a physiologic cure for OSA.

Marti et al. [67] followed a cohort of 444 patients, between the years 1982 and 1996. The cohort consisted of normals (no OSA) and those with OSA. They found that patients with untreated OSA developed a higher mortality risk than the normal population. When OSA patients were treated either with surgery (UPPP), weight loss, or CPAP, they found that mortality risk of treated sleep apneics fell to levels similar to that of the general population, regardless of treatment modality. The lack of physiologic cure (AHI < 5) should not be grounds for deciding against surgical treatment.

Because surgery may eliminate symptoms of OSA, postoperative sleep studies are obligatory to rule out the remaining disease in all patients [10]. With time, effectiveness may decrease, due to the natural aging of the body and increase in tissue collapsability. There is also the common issue of weight gain with aging. Weight gain is one of the main predisposing factors to deterioration of surgical success [50, 68]. Thus, as OSA may persist or recur with time, long-term follow-up is recommended, independent of the modality of treatment chosen [22].

Conclusion

There are many surgical modalities for the treatment of OSA, each with its own risks and benefits. Choosing the right type of surgery for each patient is the role of the surgeon.

Surgical therapy can provide major improvements in many aspects of patients' quality of life and improve survival. Surgery should be regarded as an important modality of treatment mainly when other modalities of conservative treatment (such as CPAP) have been tried without success, or in select cases when anatomical abnormalities are readily identified and can be corrected.

The concept that OSA is a chronic disease and as such requires lifelong follow-up and management also holds true for any surgical patient. The careful surgeon will constantly monitor the patient for early recurrence or worsening of OSA.

Required Author Forms Disclosure forms provided by the authors are available with the online version of this article.

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