Surgical approaches in obstructive sleep apnea syndrome: A review of techniques

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ABSTRACT

Obstructive sleep apnea syndrome (OSAS) is a highly prevalent problem of public health, which is characterized by intermittent and repetitive narrowing of the airway while sleeping. Approximately half of the patients with OSAS therapy fail to comply with continuous positive airway pressure (CPAP) because of mask-related problems, treatment-related side effects, patient attitude, or perceived lack of benefit. The aim of the surgical therapies for the treatment of OSAS is to improve airway patency by operating on selected sites of obstruction. Different surgical modalities have been developed, since different anatomical locations may be responsible for a narrow upper airway. Consequently, the surgical approach needs to be individualized for each patient. Surgical treatment of OSAS presents variable efficacy but is capable of improving mortality and morbidity rates in selected patients. However, the surgery for OSAS is not a substitute for CPAP but is a salvage treatment option for patients who have failed CPAP and other conservative treatments, or had significant side effects of device use, or have a favorable anatomy such as tonsillar hypertrophy.

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INTRODUCTION

An intermittent and repetitive upper airway collapse or narrowing during sleeping, happen to patients who suffer from obstructive sleep apnea syndrome (OSAS)[1]. The effects of OSAS syndrome are sleep fragmentation, hypoxemia, hypercapnia and increased sympathetic nervous system activation with recurring episodes of hypertension, leading to a plethora of symptoms, the main being excessive daytime sleepiness and cognitive impairment[2]. In addition, moderate and severe OSAS constitute an independent risk factor for cardiovascular disease, strokes, cardiovascular mortality, endocrine disorders and all-cause mortality[1,3-7]. The effect of mild OSAS remains controversial, since different studies suggest either an increase or no impact in morbidity and mortality[1-3]. Furthermore, a connection between OSAS and obesity has been established. This connection is not at all simple and likely combines biological and lifestyle factors[4-7].

Septoplasty and polypectomy are also common nasal operations in adults and a combination of different techniques is feasible. Septoplasty is the correction of an anatomical deformity. Polypectomy on the other hand is the removal of nasal polyps, a disease of the nose and the paranasal sinuses.

Atherosclerosis associated with OSAS is possibly attributed to an excess of free radicals by inflammation causing a dysfunction of the endothelium. Additional factors include intrathoracic pressure changes and a sympathetic response[4].

OSAS affects approximately 3% to 7% of adult men and 2% to 5% of adult women in the general population[6]. Full-night polysomnography (PSG) involves an overnight stay in a sleep laboratory with multichannel monitoring for sleep physiology and architecture, brain activity, and respiration during sleep and is the standard method used to diagnose and grade OSAS[6]. The primary treatment options include behavior modifications, continuous positive airway pressure (CPAP) devices, oral appliances, and surgery, which should be offered based on the severity of OSAS and the patient's upper airway anatomy, preferences, and risk factors[6].

It appears that altered patterns of sleep and low oxygen saturation levels, seen in OSAS, will promote specific alternations in gut microbiota. That, in turn, will elicit immunologic alterations, which are associated with OSAS-induced end-organ morbidities, such as coronary disease and hypertension[8-12]. Neurocognitive consequences of OSAS also include loss of alertness, memory deficit, reduced vigilance, impaired executive function, increased risk for automobile and occupational accidents and finally decreased quality of life[8,13-15]. Recent bibliography is even correlating OSAS to different types of cancer, such as melanoma, lung, breast and primary central nervous system cancer. This relation is ascribed to certain molecular pathways, such as the hypoxia-induced factor (HIF) pathway[10,11]. Finally, OSAS is considered to contribute to sexual dysfunction in male patients[12].

Upper airway obstruction occurs when the soft palate and/or tongue collapses posteriorly against the pharyngeal wall because of the loss of normal muscle tone during sleep. Although, upper airway obstruction in OSAS patients is not solely due to the loss of normal muscle tone during rapid eye movement (REM), people develop obstructive sleep apnea (OSA) for different reasons. The ability to understand these reasons, to easily identify them in individual patients, and develop therapies that target one or more of these reasons are the keys to unlocking new approaches for the treatment of OSAS. In line with this approach, recent advances in OSAS pathogenesis using upper airway and respiratory phenotyping techniques have identified four key causes of OSAS. A narrow or collapsible upper airway ('impaired anatomy') is the primary cause. However, the anatomical contribution to OSAS varies substantially. Indeed, impairment in pharyngeal anatomy can be modest and, in many patients (about 20%), pharyngeal collapsibility during sleep is not different for people without OSAS. Thus, non-anatomical factors or 'phenotypes' that modulate pharyngeal patency are crucial determinants of OSAS for many people. These include impairment in pharyngeal dilator muscle control and function during sleep, increased propensity for awakening during airway narrowing (low respiratory arousal threshold) and respiratory control instability (high loop gain). Each phenotype is a potential therapeutic target[16].

Different epidemiologic studies estimate that 2–17% of the adult population is affected by OSAS, with selected populations including males, individuals with high BMI (≥30 kg/m^2), and aged >60 years, being at higher risk for OSAS possibly due to anatomical crowding of the upper airway at baseline[16-21]. According to Sher et al.[18], only 1.5% of OSAS patients present a space occupying pathology. The rest (98.5%) of the cases are attributed to airway obstruction due to abnormalities of the osseous structures or the soft tissues[18].

The gold standard of OSAS treatment is CPAP appliance[19-25], which keep the airways patent during sleep. However, most of patients will not achieve long-term compliance, because of mask discomfort, skin irritation, noise, or claustrophobia[24,26-27]. Untreated OSAS and non-compliance with CPAP therapy must be taken under serious consideration, as these factors increase the risk of multiple health complications.

This article discusses surgical therapies as alternatives to conservative CPAP therapy and their relative effectiveness. Surgical therapies have variable efficacy, and decrease the morbidity and mortality associated with the disease in selected patients. There are different types of surgical procedures for the treatment of OSAS according to the heterogeneity of the anatomical cause of OSAS and the location of airway obstruction[28-38].

METHODOLOGICAL APPROACH

Diagnosis

In patients complaining of long hours of daytime sleepiness, the American College of Physicians suggests examination for OSAS with a polysomnogram (PSG) study. This examination at the same time records a patient's encephalograph (ECG), oxygen saturation (SaO_2), respiratory effort, heart and breathing rates, as well as eye and leg movements during sleep[8]. The disease is diagnosed when cyclical airway obstruction with associated oxygen desaturations and sleep arousals are identified in PSG. The number of episodes of apnea or hypopnea per hour of sleep defines the apnea-hypopnea index (AHI). An AHI <5 is considered normal. An AHI of 5–15 defines mild OSAS, 16–30 moderate, and an AHI >30 indicates severe OSAS (Table 1)[39]. The rate of the disease may be assessed with the apnea-hypopnea index (AHI) and/or respiratory disturbance index (RDI) in conjunction with the Epworth Sleepiness Scale (ESS). The RDI is similar to the AHI but also incorporates the Respiratory Effort-Related Arousals[40], while the ESS is a questionnaire used to calculate a person's somnolence during the day[41]. Sometimes a modified PSG may be performed in a home setting. Home polysomnography is cost effective, allows through-sleep assessment and accurate OSAS diagnosis. Recent technological advancements have enabled remote home polysomnography to help decrease failure rates of the technique[42], in this sense OSAS is severe if AHI >30.

Finally, it should be appropriate to stratify OSAS patients suitable for surgery into the following categories:

1. Failed compliance with/intolerance of device therapy;
2. Major complications of device therapy;
3. Patient chooses surgery and declines all other options; and
4. Patient has particularly favorable anatomy for surgery.

Presurgical evaluation

Following PSG, the pre-surgical patient evaluation in OSAS includes physical examination and flexible fiber-optic naso-pharyngo-laryngoscopy to identify potential sites of collapse. The inability of PSG to assess such sites is emphasized. Several other modalities can be implemented including lateral cephalogram, 3–D computed tomographic scan, sleep endoscopy and cine–magnetic resonance imaging (MRS) The anterior portion of the nasal cavities, from the nostril to the nasal valve (NV), is the place of highest nasal resistance to airflow, paramount to nasal physiology. There are different terminologies for the same

Table 1. Classification of OSAS severity

AHI score	OSAS severity
<5	Normal
5–15	Mild
16–30	Moderate
>30	Severe

anatomic structures in the literature[33-35].

A lateral cephalogram can help evaluate soft tissue dimensions, such as posterior airway space diameter, soft palate and tongue size, and also make other cephalometric measurements. It is limited by its 2-D nature and by realization while awake[33].

Computed tomography can provide physicians with elaborate anatomical relationships prior to an operation, but since the patients are awake during a CT scan, the predictive value of the technique to diagnose OSAS remains low. It can assist, however, in predicting positive uvulopalatopharyngoplasty (UPPP) results before surgery. Although MRI can provide details of the soft tissues, it still presents the aforementioned sleep limitation[33].

Asleep endoscopy and sleep MRI are both commonly used to evaluate surgical failures and identify residual sites of obstruction, or in complex cases in which the history and/or PSG do not appear to match the patient's symptoms. The first technique provides static images and has certain limitations. Sleep MRI, on the other hand, provides a real-time dynamic display of the upper airway with high reliability[34-38]. Awake Muller's maneuver, asleep endoscopy with CPAP, fluoroscopy and manometry can also contribute in OSAS assessment. Overall, endoscopic procedures, especially the awake Muller's maneuver and lateral cephalometry are the most prevalent diagnostic modalities[30].

Surgical therapy can be considered when CPAP therapy has failed, or in cases of an identifiable physical abnormality. The key to an effective surgical treatment involves determining the exact sites of airway obstruction or narrowing, interpreting a patients PSG data and understanding which surgical procedures are appropriate for each patient. Even if surgery is being considered as the primary treatment option, CPAP and other conservative therapies should still be considered before surgical therapy, if the consensus of the patient is appropriate.

Finally, as to drug-induced sleep endoscopy (DISE), it was pioneered at the Royal National Throat, Nose and Ear Hospital in London in 1991 but was initially introduced with a different name of Sleep Nasendoscopy. Prior to drug induced sedation, endoscopic evaluation had been reported in natural sleep by Borowiecki[33] in 1978. However, this technique was thought to be time consuming as the whole night of sleep recording was subsequently evaluated for the anatomical events.

Table 2. Indications for surgery of OSAS

Moderate to severe OSAS
Severe drowsiness during the day independently of AHI score
Comorbidities of OSAS (cardiovascular diseases etc.)
OSAS due to specific anatomic reasons
Unsuccessful conservative treatment

Objectives

Reduction of the upper airway resistance maintaining airway patency at sleep is the utmost goal of OSAS surgery. Since OSAS surgery remains debatable and elective surgery, it is important to define specific indications for surgery (Table 2)[43].

When aiming to treat OSAS surgically, it is very important to define the specific anatomical area of obstruction, since failure following OSAS surgery is a result of a remaining or a secondary airway collapse. The patterns of pharyngeal obstruction which have been proposed[30] and are subject to surgical intervention are presented in Table 3.

It is clear that when it comes to selecting a proper surgical modality, it should be a person-centered one and be in accordance with the classification of the airway obstruction sites. A thorough investigation of the different pharyngeal areas prone to collapse should be implemented prior to surgery. Riley et al.[9] presented a protocol in which patients with moderate or severe OSAS were treated surgically in two phases with >95% overall success rate. In the first phase, patients received a UPPP and/or a genioglossus advancement with hyoid suspension depending on the obstruction site. When phase I operations were considered unsuccessful, a maxillomandibular advancement was performed; 98% of patients who received the whole sequence of indicated operations were successfully treated[9].

Surgical therapy is considered successful when the RDI is reduced to ≥50% and a post-surgical RDI <20 or AHI <10. However, it appears that although such results might show an amelioration in the severity index of the disease, they might prove to be sub-therapeutic, since their impact on comorbidities of OSAS, such as hypertension, heart failure, atherosclerosis, endocrine disorders and quality of life is low. Thus, a more stringent criterion of surgical success should be established, that is AHI <10 or even AHI <5. Unfortunately, success rates greatly deteriorate as the criterion becomes stricter, i.e. success rate for phase I surgery drops from 55% to 31.5% (AHI ≤10) and to 13% (AHI ≤5). Similarly, rates drop from 86% to 45% (AHI ≤10) and 43% (AHI ≤5)[9,30,40,41]. We should emphasize that patients should be informed about surgical success rates and potential complications of the procedure before surgery[42].

SURGICAL TECHNIQUES

Several operative techniques have been proposed over the last decades aiming to control symptoms and comorbidities of OSAS. Surgical techniques, such as uvulopalatopharyngoplasty and mandibular osteotomy, still

Table 3. Sites of pharyngeal compromise

Classification	Sites of pharyngeal compromise
I	Retropalatal
II	Retropalatal and Retrolingual
III	Retrolingual

in use today, were first introduced in the late 1970s[44,45]. Nevertheless, the importance of identification of the exact sites of obstruction prior to surgery, should be highlighted once more.

The different procedures with their mechanism and sites of action are presented in Table 4. These aim to modify soft tissue and osseous structures so that pharyngeal collapse during sleep is prevented[30].

The Riley-Powell protocol is considered a cornerstone in surgical treatment of OSAS. It basically consists of a staged procedure, which involves UPPP, tongue reduction or advancement techniques and nasal surgery during its first stage. The second stage involves MMA. Further surgical modalities, such as bariatric surgery and hypoglossal nerve stimulation have been proposed, while tracheostomy remains an end-stage solution. Nowadays, several physicians choose to perform MMA from the beginning, or even combine phase I and II procedures[26].

Nasal procedures

Nasal procedures aim to reduce nasal blockage caused by bone, cartilage, or tissue hypertrophy. Such conditions can be induced by septal deviation, chronic rhinosinusitis, nasal polyps and turbinate enlargement[25,44]. In one study involving normal subjects, upper airway resistance was shown to be lower with imposed nasal breathing than with imposed oral breathing at sleep, in contrast to the supine and upright awake stature, in which nasal resistance is higher than oral resistance. Nasal procedures cannot cure OSAS because the origin of apnea is complete obstruction of the pharynx, but when combined with CPAP allow for reduced CPAP pressure, increased CPAP compliance and improved RDI and ESS scores. AHI scores are not significantly affected[46,47]. Thus, reduction in nasal resistance after nasal procedures is not significantly related to reduction in RDI[48].

Turbinate reduction is the most common nasal surgery. Debulking hypertrophied turbinate decreases airway resistance while maintaining normal turbinate function[48]. Radiofrequency turbinate reduction is a normally invasive strategy performed under local anesthesia in an office setting. Septoplasty and polypectomy are also common nasal operations in adults and combination of different techniques is feasible.

Uvulopalatopharyngoplasty (UPPP)

UPPP constitutes the most common surgical procedure in OSAS patients. The operation removes excess oropharyngeal tissue, the uvula and portion of the soft palate, which are common sites of obstruction OSAS patients. UPPP is usually accompanied by tonsillectomy. The operation requires hospitalization[9]. It is selected in patients with mild to moderate OSAS, and most importantly it meets highest success rates in patients with type I upper airway obstruction[49].

Success rate of the technique is 33–50%[17,25,43], while rate of snoring control is 70–90%[50]. In addition, cure rates range from 16.1% to 24%. Cure after UPPP is related to young age, lower BMI, lower AHI before surgery and higher oxygen saturation nadir[51]. It should be mentioned, however, that surgical results from UPPP diminish over time and that 20–30% of patients experience long-term adverse effects, such as velopharyngeal incompetence, swallowing disorders and throat dryness[52-54]. In addition, the following pitfall related to UPPP should be avoided. Since UPPP most often treats snoring, while persistence or a relapse of OSAS usually occurs, further polysomnographies should

Table 4. Surgical techniques and mechanism of action

Mechanism of action	Types of compromise	Techniques
Soft tissue excision	I	UPPP Laser-assisted uvulopalatoplasty Uvulopalatal flap
	II	Laser midline glossectomy/ lingualplasty Radiofrequency tongue base ablation Tongue base reduction with hyoepiglottoplasty
	III	Uvulopalatopharyngoglossoplasty
Osseous and soft tissue techniques	I	Transpalatal advancement pharyngoplasty
	II	Mandibular advancement Genioglossal advancement Sliding genioplasty Hyoid myotomy and suspension
	III	Maxillomandibular advancement
Bypass	III	Tracheotomy

be performed to detect concealed OSAS[32]. Nevertheless, UPPP, like nasal procedures, has been shown to be useful in lowering CPAP pressure requirements, improving CPAP compliance in certain patients[45]. Laser-assisted UPPP is generally not recommended because no statistically significant amelioration is observed. Additionally, there is risk for post-operative edema of the upper airway, which may require urgent tracheostomy[25,42,43].

On the other hand, uvulopalatal flap (UPF), has been reported to result in an 82% success rate, a reduced risk of velopharyngeal insufficiency and reduced post-operative pain. Very long and soft uvulas and soft palates constitute a contraindication for this operation[32,43].

Transpalatal advancement pharyngoplasty (TPA) is considered to have better results related to retropalatal airway diameter and compromise, and to surgical success in comparison with sole UPP. TPA is a combination of excision of a posterior part of the hard palate along with UPPP, followed by advancement of the flap[50,51].

Palatal implants

Palatal implants, also known as Pillar procedure, are performed in order to treat snoring and mild to moderate cases of OSAS. Three polyester rods are placed in the soft palate that initiate an inflammatory response. The resulting fibrosis of the surrounding tissues stiffens the soft pallet. This operation may be performed under local anesthesia and shows 24–44.8% reduction in AHI, significant amelioration in quality of life, snoring visual analog scale, and ESS. As an adverse effect, implant extrusion is rarely observed[43,52].

Surgery of the tongue

A common area of upper airway collapse lies in the retrolingual area, in patients with an enlarged base of the tongue[49]. Enlarged lingual tonsils may also be present[45]. Tongue surgery consists of both tongue reduction and genioglossus muscle suspension procedures. All tongue procedures are considered to improve AHI, daytime somnolence and quality of life[44]. Tongue reduction procedures include radiofrequency ablation (RFA), reduction glossectomy and transoral robotic surgery base of tongue reduction (TORS BOT). These procedures are performed in patients with mild to moderate OSAS who cannot tolerate or are unwilling to adhere to CPAP therapy[42].

In posterior midline glossectomy, a midline lingual part is excised, leading to reduction of the mass of the tongue. Success rates range from 25% to 83%[44]. Serious complications, like post-operative bleeding and edema may occur that may necessitate a protective tracheostomy. RFA uses a radiofrequency probe to help debulk the tongue. Multiple sessions for several weeks are required[26,42,44]. The success rate of the procedure is low, estimated at 36%. The greatest benefit of the operation is snoring reduction. Reduction glossectomy, improves AHI and ESS. The surgical success rate is 60%.

Novel TORS BOT helps decrease the volume of the base of the tongue implementing operative debulking assisted by a surgical robotic device. In a study by Cambi et al., a multilevel transoral robotic operation was implemented, performing tongue base reduction, expansion sphincter pharyngoplasty and septoplasty in one stage. A 60% success rate was achieved, which is comparable to other studies presenting multilevel single-stage techniques[55-57].

Tongue suspension procedures include non-absorbable sutures passed anteroposteriorly towards the base of the tongue and then tethered to the mandible. A low success rate is observed. According to another study, long-term results are met in 42% of patients subject to tongue suspension, while a 33% rate is met in patients following RFA of the tongue. Both procedures are minimally invasive and well tolerated. The authors conclude that lingual RFA should be preferred, since it is even less invasive and repeatable[54]. The aforementioned RFA technique is an adjunct to OSAS treatment, and not a main intervention[42]. As already mentioned, sole tongue surgery meets low long-term success rates, but it can be effective in a multi-level surgical protocol. As shown in a meta-analysis by Handler et al.[43], patients who received a sole tongue suspension operation reached a success rate of 36.6%. In contrast, combinatory procedures were much more efficacious. Tongue suspension with UPPP had a success rate of 62.3%, genioglossal advancement UPPP 61.6% and tongue suspension with hyoid myotomy and suspension 61.1%.

Skeletal surgery

Skeletal surgery for OSAS has been proposed in all three types of OSAS but is most often selected in type II or III. It can also be combined with surgery of the retropalatal space, when indicated and can be implemented in a multilevel surgical protocol. Advancement techniques aim to augment tension of the genioglossus, geniohyoid and muscles of the pharynx, releasing the obstructed retro lingual space of the sleeping patient. An advancement of 8 to 14 mm is typically intended[58-61].

Genioglossal advancement

This procedure is usually performed under local anesthesia. A bicortical anterior osteotomy is performed between the mandibular canine teeth roots and the inferior mandibular edge. The anterior portion of the osteotomized segment is removed and the posterior cortex supporting the origin of the genioglossus muscle is advanced and rotated in a vertical manner producing tension of the muscle.

Success rates of the technique range between 39% and 78%[52]. Genioglossal advancement is usually performed in combination with UPPP and is successful in about 61% of cases. Failure of the technique may occur because the advancement of the genioglossus is short. Additionally, a lax tongue usually affects the surgical results negatively, since the airway obstruction remains. Thus, it is of great importance to determine the extent of tension needed by advancement of the genioglossus muscle to remove airway blockage. The tension-to-width ratio is a possible indicator for surgical success following genioglossal advancement. Complications include tooth injury, fractures of the mandible, and dysphagia[56,62-65].

Sliding genioplasty

This is a technique which can be considered in patients with notable retrognathia and a significant risk for teeth loss, who are not eligible for genioglossal advancement. This patient category presents with retrognathia and a foreshortened mandibular body. A portion of the anterior inferior mandibular border is dissected and advanced, leading to advancement of the geniohyoid muscle solely. The technique is only recommended in retrognathic patients with mild OSAS and retropalatal blockage, while it can be combined with functional rhinoplasty. It is not indicated in all patients with OSAS, since the genioglossus muscle is not affected. A combinatory operation with sliding genioplasty and genioglossus muscle advancement has also been described in retrognathic patients[57-58,66-70].

Hyoid myotomy and suspension

In this procedure, the hyoid bone is mobilized and suspended to either the mandible or the thyroid cartilage. A success rate of 18% to 77% has been reported in different studies, in which UPPP surgery was also performed. The procedure can also be combined with genioglossus advancement with 22–77% success rates. Hyoid suspension can increase retro lingual space. Advancement of the hyoid advances the epiglottis anteriorly[52,71,72].

Maxillomandibular advancement (MMA)

MMA uses simultaneous advancement of the maxilla and mandible to enlarge the retro lingual airway[25,42,73,74]. Esthetic defects, nonunion and malocclusion are common adverse effects. MMA is indicated for severe OSAS when the patient is not able to tolerate CPAP or in the presence of significant maxillomandibular deficiency[25,42]. Its success rate is estimated as high as 87% but should be considered only in extreme cases of OSAS because facial deformities can be induced[39,75,76]. Another study showed that 93.3% of patients reported significant quality of life improvement (productivity, social outcomes, physical activity)[54,55,77]. MMA can be performed either as a sole or as a phase II operation with high success rates, since it leads to enlargement of both the retropalatal and the retro lingual pharyngeal spaces[43,78,79].

Stimulation of hypoglossal nerve

Stimulation of hypoglossal nerve is the newest surgical treatment for OSAS patients. An impulse generator is implanted in the chest wall. The generator has an electrical lead that senses diaphragmatic contraction and simultaneously sends an impulse down a second lead that activates the genioglossus muscle through the hypoglossal nerve. This stimulation causes contraction of pharyngeal structures during inspiration and prevents the collapse of the airway[59,60,80-83]. The sustained success rate is 74%, with a significant reduction in AHI 36 months after the intervention[61]. Adverse events have been reported in 2% of patients after surgery.

Tracheotomy

This procedure is considered as the gold standard surgical technique against OSAS, since it completely bypasses the upper airway including any anatomical or physiological obstructions[25,30]. It is invasive and has a physiological impact on the patient's life, but significantly improves AHI and ESS score. It constitutes an option for heavily obese patients, for patients with severe craniofacial abnormalities and in cases of failure of other treatment modalities. Tracheotomy is considered highly effective in patients with uncomplicated OSAS, but treatment limitations exist in patients with complications from OSAS, such as cardiopulmonary disease[62,84].

Bariatric surgery and OSAS

OSAS is encountered in >45% of bariatric patients screened with a sleep study[63]. Additionally, body weight increased by 10% is expected to lead to a six-fold increase in risk to develop moderate or severe OSAS. Obesity surgery is traditionally indicated in persons with BMI >40 kg/m^2 or over 35% and grave comorbidities. In patients with OSAS, such procedures are considered adjunctive to first-line modalities like CPAP[64,85]. Surgical techniques include mainly restrictive, such as sleeve gastrectomy, mainly malabsorptive, such as biliopancreatic diversion and combined operations, such as Roux-en-Y gastric bypass.

Weight loss can improve BMI and moreover OSAS severity, while bariatric surgery offers obviously greater outcomes than conservative weight loss. Specifically, in a study by Haines et al.[54], AHI has been reported to decrease from 51±4 to 15±2 postoperatively with a BMI drop from 56+1 to 38+1[59,60]. However, a 40% remission of OSAS two years after obesity surgery is observed and thus a closer follow-up is recommended[65].

DISCUSSION

OSAS is a frequently met disorder in the adult population, which causes significant cardiovascular, endocrine, neurocognitive morbidity and mortality and is even correlated to several types of cancer. CPAP remains the gold standard in OSAS treatment, while as a major drawback, compliance to CPAP is usually insufficient. Although many alternative conservative modalities have been proposed, surgical intervention remains an important treatment option.

Principally, a proper diagnostic battery should be implemented, so that the exact sites of obstruction are detected. It is well recognized that surgical failure is a result of remaining or relapsing compromise of the upper airway[30]. A proper classification should be implemented as shown in Table 3.

Randomized controlled trials (RCT) are considered the highest level of evidence, but they can pose methodological challenges in the field of surgery[65-67], for instance performing placebo/sham surgical procedures on patients undergoing general anesthesia. When the implementation of RCTS is unethical, non-RCTs are of value in the evaluation of surgical outcomes[72,73].

OSAS is associated with increased risk of hypertension and other cardiovascular disease and therefore must be treated. Surgical therapy provides significant benefits including the improvement of reaction time, quality of life and motor vehicle crash risk[62,70,76]. CPAP treatment is highly efficacious but has variable effectiveness as it depends on patient compliance[74]. On the other hand, surgery may have variable efficacy but is independent of compliance. Deterioration after surgery due to increasing age and body weight necessitates long-term follow-up independent of the modality of treatment chosen[77-88].

CONCLUSIONS

According to epidemiologic data, 25% of patients have only one level of obstruction, while 75% have multiple obstruction sites. When surgery addresses multiple levels of obstruction, the success rate may reach about 95%[9]. Single-site surgery presents poor success rates when multilevel obstruction is present. It is of interest that individuals with a first stage UPPP and a second stage MMA had significantly lower success rates relatively to those with a single-stage MMA. This result could, nevertheless, be attributed to more severe disease in the first patient category[69].

As already highlighted throughout the text, single-stage multilevel operations are frequently implemented nowadays, in an effort to treat simultaneously different areas of known pharyngeal compromise. Thus, nasal, retropalatal and retrolingual surgical modalities may be combined, providing improved success rates. Specifically, UPPP is frequently performed along with a retrolingual space technique. Success rates reach 66%, while multilevel hypopharyngeal modalities, such as RFA of the tongue with tongue suspension, are not as efficient[70,71].

Conservative therapy remains the first-line treatment for patients with OSAS. Surgery of the upper airway, on the other hand, remains controversial because of the low success rates (35–62%) observed in various studies[52,81-84]. Because there are many surgical modalities for treatment of OSAS patients, a stepwise approach should be used. Such an algorithm would be sole CPAP use to CPAP with oral devices and/or medications and ultimately to surgical operation. Surgical correction of structures of the nose, pharynx, tonsils and tongue should be attempted before more invasive procedures such as MMA, UPPP and hypoglossal nerve stimulation. Tracheostomy should be a last line option. Postoperative sleep studies should be performed for the assessment of recurrent disease and reevaluation of the need for CPAP therapy[26,85-88].

It should be said in regard to the state of the art and future directions of surgery for OSAS, future studies should explore the role of UAS in conjunction with other modalities such as oral appliance therapy, upper airway surgery, lowering nasal resistance, weight loss, and positional therapy.

CONFLICTS OF INTEREST

The authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest and none was reported.

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