Overview of Surgical Therapies for Obstructive Sleep Apnea: a Concise Review Literature

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ABSTRACT

The surgical therapy of Obstructive Sleep Apnea (OSA) requires addressing anatomical obstructions or collapse of the pharyngeal airway by skeletal and soft tissue surgeries. Numerous surgical options have been documented for OSA therapy with varying success. OSA surgery is vital when patients refuse continuous positive airway pressure (CPAP). The aim of this article is to review surgeries for OSA and the effectiveness of each surgery in terms of Epworth sleepiness scale (ESS), Apnea Hypopnea Index (AHI) or Respiratory Disturbance Index (RDI) reduction.

Keywords: Obstructive sleep apnea; continuous positive airway pressure; epworth sleepiness scale; apnea hypopnea index; respiratory disturbance index (Siriraj Med J 2020; 72: 87-94)

INTRODUCTION

Obstructive sleep apnea (OSA) is a medical condition characterized by episodes of partial (hypopnea) or complete (apnea) constriction of the upper airway during sleep. Patients with untreated OSA are usually afflicted by excessive daytime sleepiness (EDS), which is a symptom that has been associated with an increased risk of motor-vehicle[1] and workplace accidents.[2] Moreover, several reports have linked OSA with various cardiovascular events such as stroke,[2,3] myocardial infarction,[4] and hypertension.[5] Nowadays, the usual first-line therapy for OSA is continuous positive airway pressure (CPAP). Although CPAP is still regarded as the gold-standard therapy for OSA the non-adherence rate of patients to CPAP has been documented to be as high as 34.1% (based on studies over a twenty-year time frame).[6] Consequently, CPAP non adherent patients are then managed by surgery either to increase CPAP compliance[7] or to effectively reduce the Apnea Hypopnea Index (AHI) or Respiratory Disturbance Index (RDI) to a level that alleviates the need for CPAP.[8] However, each surgical modality comes with distinct pros and cons, and it is up to the clinician to weigh them for the patient's best interest. This article serves to review the surgical treatments for OSA.

Diagnosis of OSA

Polysomnograhy (PSG) is the most accurate method for diagnosing the presence of OSA, and the severity of OSA is usually based on the Apnea Hypopnea Index(AHI): Mild OSA (5-14.9), Moderate OSA (15-29.9) and Severe OSA(≥30).[9] The PSG is incapable of determining the exact anatomical location of the obstruction or collapse. Anatomical obstructions could be well demarcated deformities of the soft tissues that

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TABLE 1. The abbreviations were used in this concise review literature.

Full name word	Abbreviation
Obstructive sleep apnea	OSA
Excessive daytime sleepiness	EDS
Continuous positive airway pressure	CPAP
Apnea hypopnea index	AHI
Respiratory disturbance index	RDI
Polysomnograhy	PSG
Drug induced sleep endoscopy	DISE
Velum, oropharynx lateral wall, tongue base and epiglottis	VOTE
Uvulopalatopharyngoplasty	UPPP
Genioglossus advancement	GGA
Laser assisted uvulopalatoplasty	LAUP
Radiofrequency ablation	RFA
Radiofrequency	RF
Maxillomandibular advancement	MMA
Bilateral sagittal split ramus osteotomy	BSSRO
Hypoglossal nerve stimulation	HGNS
Transoral oral robotic surgery	TORS

can be visualized through physical examinations, fiber optic pharyngoscopy and lateral cephalograms. These obstructions generally remain constant, regardless of whether the patient is awake or sleeping.[10] Some forms of obstructions or collapse occur as a result of a narrowing of certain anatomical sites such as the lateral pharyngeal wall or tongue during sleep.[10] Complete concentric collapse of the velum during sleep is one of the main determinants of failure of OSA surgery.[11] Therefore, drug induced sleep endoscopy (DISE) has become vital for selecting the right treatment plan in OSA cases.[12] The main anatomical structures that are visualized and evaluated via DISE are the Velum, Oropharynx lateral wall, Tongue base and Epiglottis (VOTE).[12] Besides aiding in diagnosis, DISE post-operation gives an objective and dynamic visualization of the airway, and provides a key marker for success which is the stability of the lateral pharyngeal wall.[13]

Tracheostomy

The tracheostomy as a procedure for resolving hypoventilation was first proposed in 1965 by Valero and Alroy, and the case report featured a 55 year old male with chronic traumatic micrognathia who complained of excessive sleepiness which improved after tracheostomy.[14] Multiple preceding reports up until the early of 1980s reaffirmed the tracheostomy as the surgery of choice for OSA, particularly in morbidly obese patients.[15-17] However, the complications of tracheostomy include minor hemorrhage, cuff leakage, and in severe cases tube obstruction which could lead to death.[18] There is an inevitable reduction in the quality of life of patients following tracheostomy due to speech problems, body image issues, and daily physical limitations.[19] Therefore, the American Academy of Sleep Medicine recommended that tracheostomy should only be used when all other treatment options have been exhausted and failed or when clinically urgent.[20]

Nasal surgeries

The consensus on nasal surgery as a stand-alone procedure for OSA is that it improves daytime sleepiness and snoring, but does not reduce AHI scores.[21] Nevertheless, OSA patients with increased nasal resistance from hypertrophic inferior turbinate and deviated septum are often non-adherent to CPAP.[22] Nasal surgeries increase the nasal airflow and reduce the pressure requirements on CPAP therefore improving CPAP adherence.[21,22] Nakata et al.,[22] found significant reduction of nasal resistance measured via Rhinomanometry after inferior turbinectomy and submucus resection of nasal septum was done on CPAP non-compliant patients. ESS scores post-op improved from 11.7±4.1 to 3.3 ±1.3.

Uvulopalatopharyngoplasty

The Uvulopalatopharyngoplasty (UPPP) is a surgery that was first developed by Ikematsu in the 1950's for the reduction of snoring, his findings were later published in 1964.[23] In 1981 Fujita et al.,[24] introduced the UPPP technique (Fig 1) to English-speaking surgeons.

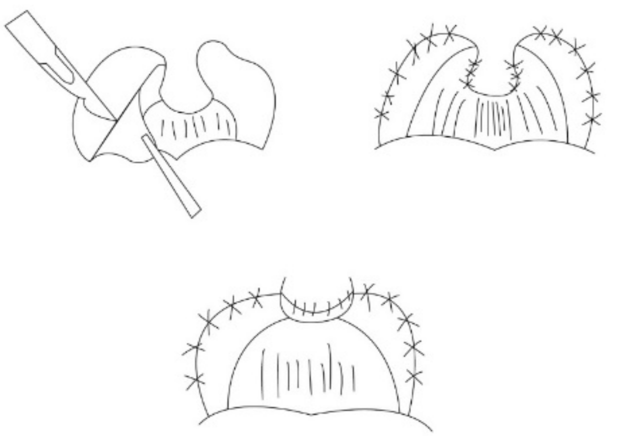

Fig 1. Fujita Uvulopalatopharyngoplasty.

Thereafter, the UPPP became a common procedure despite the lack of evidence supporting its efficacy especially as a stand-alone surgery in the treatment of moderate to severe OSA.[20] Sher et al., concluded in a meta-analysis that only 40.79% of patients who had undergone UPPP exhibited success in terms of AHI reduction of 50 % or AHI less than 20.[25] The UPPP entails the widening of the oropharynx space by means of shortening the uvula thus, long-term side effects include dysphagia, nasal regurgitation, dysphonia, and throat pain.[26] When a staging system that is based on the anatomy of the palate is used, the success of the UPPP could be more predictable.[27] Friedman et al., had success in 80.6% of Friedman stage 1 (entire uvula, tonsils or pillar are visible when tongue is in a neutral position) cases that had UPPP. [28]

Genioglossus advancement with/without hyoid myotomy

Riley et al., first documented success with genioglossus advancement (GGA) and hyoid myotomy as part of a multi-step surgical protocol. GGA was done via a genial tubercle rectangular window which was advanced and rotated before fixation whereas hyoid myotomy involved the suspension of the hyoid bone over the thyroid cartilage.[29] Neruntarat replicated the same technique under local anesthesia on 31 OSA patients with hypopharynx obstruction as diagnosed by polysomnography and awake nasopharyngoscopy, and the RDI improved from 48.2±10.8 to 14.5±5.8.[30] Both studies utilized additional UPPP for the correction of retropalatal obstructions. In 2017 Vargo et al.,[31] documented recently GGA as a stand-alone surgery for OSA with success in terms of mean AHI reduction (36/h to 4.3/h). Vargo et al., also advocated a sliding genioplasty (Fig 2) as opposed to genial tubercle window in isolated GA cases for better cosmetic outcomes and the possibility of larger advancements with glossoplexy sutures.[31]

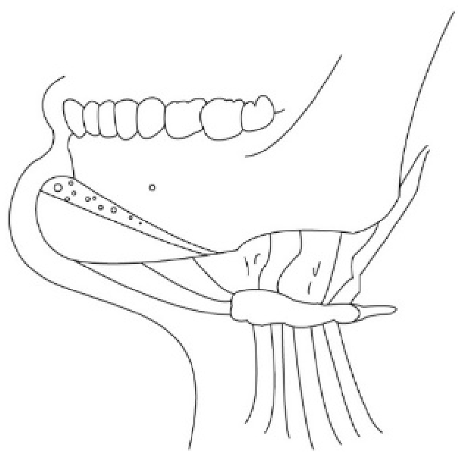

Fig 2. Sliding Genioplasty. The genial osteotomy should involve the anterior inferior border of the mandible to advance the genioglossus and suprahyoid muscles.

Laser assisted uvulopalatoplasty

Laser assisted uvulopalatoplasty (LAUP) is an outpatient procedure for OSA therapy that could be performed under local anesthesia without the risk of hemorrhage. Kamami[32] was the first proponent of the LAUP as a treatment modality for OSA. In a 1994 publication' Kamami[32] documented 43.4% resolution of OSA, with only 13% non-responders after multi session LAUP. In a similar vein, Peng et al., reported a 79.17% rate of effectiveness based on polysomnography results from 96 patients who had received LAUP.[33] Contrarily, Göktas Ö et al., found worsening AHI scores (>5/h) post LAUP in 12 out of 25 patients.[34] A recent meta-analysis and systematic review by Camacho et al., recommended clinicians either to abandon LAUP as a therapy for OSA or to perform it with caution because individual data revealed 44% of cases with worsening AHI following LAUP.[35] Camacho et al., attributed the deterioration of OSA after LAUP to the destruction of the soft palate surface which leads to the reduction of the reflexogenic dilation of the upper airway.[35]

Radiofrequency ablation

Radiofrequency ablation (RFA) is considered a conservative procedure that involves the insertion of a Radiofrequency (RF) electrode probe into the submucosa of the soft palate or the tongue to decrease the size of these structures. RFA is usually delivered at low temperatures to prevent post-operative pain and discomfort. Powell et al., pioneered the use of RFA in mild sleep disordered breathing in 1998 by inserting a custom RF electrode to the soft palate under local anesthesia, and after 8 to 12 weeks, radiographic results showed a mean shrinkage of 5.5±3.7 mm which objectively improved ESS scores (8.5±4.4 to 5.2±3.3) and the mean 95th percentile inspiratory nadir (-19.71±5.29 cm to -12.78±6.28) cm H_2O.[36] Powell et al., followed up in 1999 with the RFA of the dorsal surface of the tongue demonstrating positive results in tongue size reduction (-17%), mean RDI (39.6 to 17.9) and mean SaO_2 nadir (81.9% to 88.3%).[37] Additionally, Riley et al., found promising results (mean AHI 35.1 to 15.1) after multiple RFA applications to the ventral and dorsal surface of the tongue. In a study on Thai patients, Sonsuwan et al., documented 16 out of 51 patients that had AHI scores of < 5 following RFA of the soft palate. These 16 patients had lower baseline AHI scores pre-op which was inferred as a key factor of success in RFA for OSA.[38]

Maxillomandibular advancement

Maxillomandibular advancement (MMA) routinely involves a Lefort 1 osteotomy (Fig 3) and Bilateral Sagittal Split Ramus Osteotomy (BSSRO) (Fig 4) with or without genioplasty advancement. Although MMA is usually performed on moderate to severe OSA patients with retrognathic maxilla and mandibles, some OSA cases with class 1 skeletal relationships could be candidates for MMA as well.[39] Morbidly obese patients who are non-adherrent to CPAP have been documented to respond favorably after MMA.[40,41] Despite morbid obesity not being a definite contraindication for MMA, the effectiveness of MMA in this group of patients remains inconclusive due to the lack of data and insufficient studies.[42] Clear indications to perform MMA as a first line surgical therapy includes retrognathic jaws, severe OSA and cases with complete concentric closure of the velum and lateral pharyngeal wall diagnosed with DISE.[38]

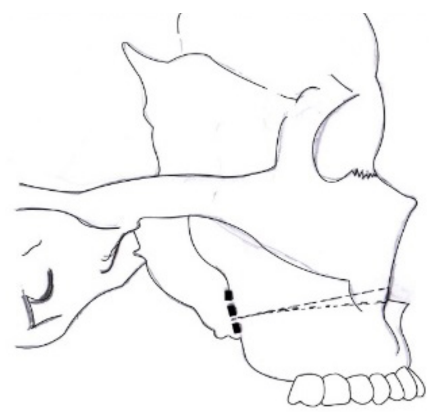

Fig 3. Lateral view (1 side) of a Lefort 1 osteotomy. The thick dotted lines show the osteotomies at the pterygomaxillary junction. The thin dashed lines show the horizontal osteotomies that form a wedge shape which facilitates anti-clockwise movement of the maxilla.

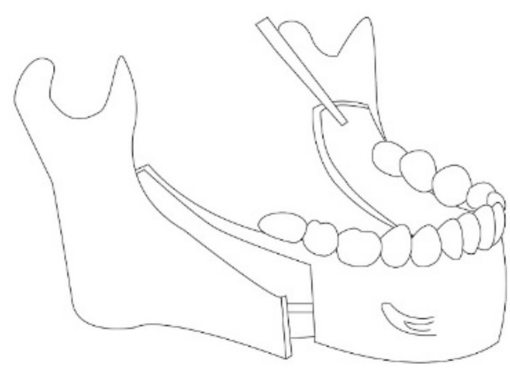

Fig 4. Bilateral sagittal split osteotomy of the mandible. Necessary precautions are necessary to prevent inferior alveolar nerve injury.

The Stanford MMA technique developed by Powell and Riley has allowed larger advancements, up to 10 mm in the maxilla and 11 mm in the mandible which effectively expands the upper airway space without the need for hyoid suspension.[43] An updated version of this technique involves Lefort 1 and Bilateral Sagittal split osteotomies with the maxillomandibular complex rotated in an anti-clockwise manner to maximize esthetic results and tension of the lateral pharyngeal wall.[39]

The success rate of MMA for OSA when performed in either phase 1 or phase 2 of the Stanford protocol has been reported to be more than 90% in patients with BMI<40 and 81% in patients with BMI>40.[43] Studies that conducted 3-dimensional Computer Tomography analysis of the upper airway in a static model post MMA documented improvement in retropalatal and retroglossal parameters.[44,45] With the aid of DISE, dynamic measurements were recorded post MMA which revealed the lateral pharyngeal wall tension during sleep as a significant marker for success.[13] Kastoer et al., documented promising results with MMA for treating OSA patients with complete concentric collapse of the velum by eliminating the complete closure thereby reducing the AHI values by 9.9 ± 7.2 events per hour from a baseline of 40.2 ± 25.6 events per hour.[46]

Despite the high success rates and predictability of MMA as a treatment for OSA, the advancement of the maxillomandibular complex will undoubtedly alter the facial aesthetics of an individual. Li et al., conducted a questionnaire survey on patients 6 to 12 months after MMA for OSA, and 55% (24/44) of the patients reported feeling more attractive or youthful whereas 4 patients felt unfavorable changes to their facial appearance.[47] Large Lefort 1 advancements causes nasal flaring. Liu et al., reported the need for corrective nasal surgery in 18.7% of patients after MMA.[48] These unfavorable cosmetic results after MMA could be more pronounced in Asians, because Asians tend to have lips that are more outwardly projected[49] and flatter nasal bridges.[50] With this in mind, Liao et al., proposed a modified MMA technique for Asians that added anterior segmental osteotomies from premolar extraction sites, and they found a marked reduction in mean AHI scores (41.6±19.2/h to 5.3±4.0/h) with improved facial aesthetics post operation.[50] Nonetheless, according to Liu et al., MMA in Asians improves their facial appearance therefore surgeons should not be deterred from using MMA as a modality to resolve OSA in Asians as long as proper planning is done prior to surgery.[51]

Recently, a prospective multicenter study which evaluated the success of MMA for OSA reported significant improvements in mean ESS (13.3 to 4.9) and AHI (39.6 to 7.9) values.[52] These results are consistent with the 2016 meta-analysis by Zaghi et al., which documented 98.8% improvement in AHI and RDI values after MMA, based on 45 studies with a total of 518 unique cases.[53] Every surgery carries risks and potential complications, likewise MMA is an invasive surgery that could cause numbness, pain and swelling around the maxillofacial region.[53] Adverse events such as plate exposure and wound infection especially in the mandible may arise following MMA surgery.[52]

Hypoglossal nerve stimulation

In 1993 the influence of hypoglossal nerve stimulation (HGNS) on the upper airway was first studied in cats by Schwartz et al.[54] In 2011 Eastwood et al., conducted the first human trials with HGNS, with 21 CPAP non-compliant patients with moderate to severe OSA who were included in that trial, and 19/21 had polysomnography results at baseline and 6 months after HGNS device installation. AHI scores improved from 43.15±17.5/h to 19.5±16,7/h, ESS scores reduced from 12.1±4.7 to 8.1±4.4.[55] Subsequently, a multicenter prospective single-group clinical trial (STAR trial) with 126 participants was performed to assess the efficacy of HGNS for moderate to severe OSA, and the mean AHI demonstrated improvement after 12 months of HGNS (32.0±11.8 to 15.3±16.1).[56] Additionally, 116 of the 126 participants from the STAR trial were reviewed again after 36 months, and 98 agreed to a polysomnography test at 36 months after HGNS implantation. The results demonstrated stable AHI and ODI in these participants, thus, proving the long-term effectiveness of HGNS for moderate to severe OSA.[57] HGNS offers CPAP non-compliant OSA patients who are averse to facial skeletal changes from MMA, an effective second-line treatment option. However, one of the contraindications in HGNS is the complete concentric closure of the velum during DISE examination, so these cases are best treated with MMA.[39]

Palatal implants

Palatal implants or pillar implants are plastic implants that are inserted into the soft palate to stiffen the soft palate in OSA or snoring (Fig 5). Pillar implants have been largely effective in mild to moderate OSA.[58,59] In 2008 A randomized double-blinded placebo clinical trial was conducted by Friedman et al., with encouraging results after palatal stiffening with polyester implants (AHI reduction was -7.9±7.7).[58] In 2013, a meta-analysis published by Choi et al., found improved ESS and AHI scores post pillar implantation in mild and moderate OSA. Pillar implants were also found to have an overall low complication rate which was mostly trivial in nature.[59]

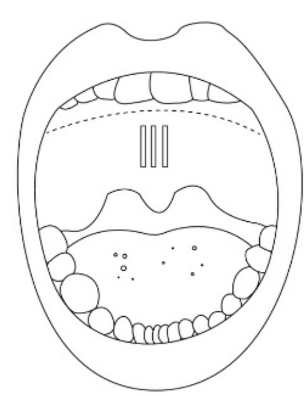

Fig 5. Pillar/palatal implants. The implants help stiffen the palate to prevent collapse.

Transoral robotic surgery

Transoral oral robotic surgery (TORS) was introduced by Vicini et al., and they documented tongue base reduction, supraglottoplasty, nasal surgeries and UPPP with the Da Vinci Robot.[60] Vicini et al., reported AHI reduction in 8 out of 10 patients after TORS, although 2 patients had worsening AHI.[60] In 2019, Vicini et al described TORS supraglottoplasty and tongue base reduction in detail, and they advocated TORS due to the precise dissection and acceptable surgical time (30minutes for tongue base reduction, and 15 minutes for Supraglottoplasty).[61] Despite accurate and minimally invasive surgeries, TORS is still not cost effective enough to warrant widespread use. Because of the price of the Da Vinci Surgical System, only selected OSA cases with tongue base hypertrophy and epiglottis collapse could potentially benefit from TORS.

DISCUSSION

CPAP is recommended as the first-line therapy in adult OSA cases but non-compliance remains a tough conundrum for patients and clinicians. McEvoy et al., published an alarming study in the New England Journal of Medicine which documented the ineffectiveness of CPAP for preventing cardiovascular events in moderate to severe OSA cases.[62] These findings coupled with the CPAP non-compliance rate could surmise a need for a shift in ideology wherein surgery is placed as a first-line therapy which fixes the etiology of OSA, particularly in cases with notable anatomical obstructions. Rotenberg et al., concluded in a systematic review that CPAP should no longer be regarded as gold-standard therapy, because of the high non-compliance and the long-term success of various surgical options. A glaring deficiency in the majority of CPAP studies is the short-term follow-up compared to the longer follow-up period in many surgical trials.[63]

MMA is currently deemed as the most effective surgical modality aside from tracheostomy for moderate to severe OSA. The advancement of the maxillo-mandibular complex causes an increase in the width of the upper airway length and tension of the lateral pharyngeal wall at the expense of facial aesthetics for some patients. Therefore, proper treatment planning and careful consideration of the baseline skeletal anatomy is needed for an acceptable outcome. Although a modified MMA technique with anterior segmental osteotomies to accommodate Asian anatomy showed promising results,[50] further research with long-term follow ups and larger samples are required to generalize this effectiveness. UPPP is very effective in selected mild to moderate OSA cases based on Friedman's staging system. CPAP non-compliant patients require thorough examination of their nasal anatomy via nasal endoscopy because nasal surgeries are proven to increase CPAP compliance. Some OSA patients that are ideal candidates for MMA may refuse MMA, in these cases, OSA can be managed with a combination of UPPP, nasal surgeries and HGNS.[64]

OSA is a chronic disease with no definite cure, and Liu et al., proposed an extension of the Stanford protocol when they documented for the first time a case of relapsed OSA in a 65 years male previously treated with 2 phases of surgeries: MMA when he was 49; UPPP, septoplasty and RFA of tongue when he was 60.[65] The latest surgery on the patient was the implantation of a HGNS device which reduced ESS to 6 and effectively reduced AHI to 1 or less depending on sleep position.[65] The authors of this review believe that customized treatment planning and multiple surgeries are necessary for the long-term stabilization of moderate to severe OSA. Therefore, ENT surgeons and oral and maxillofacial surgeons who deal with OSA should be equipped with all the surgical skills to offer patients the most appropriate treatment plan.

CONCLUSION

CPAP non-compliant patients with moderate to severe OSA require surgical therapy to either resolve OSA or to increase CPAP adherence. Further research in each surgical modality for OSA should be conducted for assessing the efficacy and long-term success rates. Currently, MMA is the only surgical modality aside from tracheostomy that could provide consistent AHI and RDI reduction in moderate to severe OSA caused by multilevel obstructions, although research documenting MMA as an isolated first line procedure is scarce. As of today, we can conclude that moderate to severe OSA in CPAP non-compliant patients is best treated with surgeries that fix multilevel obstructions. Additionally, Hypoglossal nerve stimulation could play a more important role in the future in cases with relapsed OSA who have already undergone multiple surgeries.

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