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Treatment Modalities for Obstructive Sleep Apnea (Multi-Level Surgical Approaches in OSA)

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Abstract:

Obstructive sleep apnea (OSA) is a common sleep-related breathing disorder characterized by recurrent episodes of upper airway collapse during sleep, resulting in intermittent hypoxia, disrupted sleep architecture, and reduced quality of life. Although continuous positive airway pressure (CPAP) remains the standard first-line therapy, its long-term use is often limited by patient intolerance or poor adherence. Surgical intervention offers an effective alternative, particularly for patients with anatomical contributors to airway obstruction or those unable to tolerate CPAP therapy. Multi-level surgical approaches have gained increasing clinical importance as OSA commonly involves obstruction at more than one anatomical level, including the nasal airway, oropharynx, and hypopharynx. Identification of collapse sites through drug-induced sleep endoscopy (DISE) has improved surgical planning and individualized treatment. Multi-level surgery aims to enlarge airway lumen, reduce collapsibility, and restore airway stability during sleep, leading to improved respiratory parameters and enhanced health-related quality of life.

Keywords: Obstructive Sleep Apnea (OSA); Multi-Level Surgery; Upper Airway Obstruction; CPAP Intolerance; Drug-Induced Sleep Endoscopy (DISE); Palatal Surgery; Tongue Base Surgery; Hypopharyngeal Collapse; Sleep Surgery; Quality of Life.

Introduction:

Sleep surgery has come a long way in the three decades since the advent of the original phase 1 and 2 Stanford algorithm by Riley and Powell. Phase 1 involves multi-level surgery including tonsillectomy and uvulopalatal flap with genioglossus advancement (GA). Inadequate responders to phase 1 are recommended phase 2 surgery: maxillomandibular advancement (MMA). This protocol compared favorably to positive airway pressure (PAP) therapy, especially with the inclusion of MMA (**1**).

Sleep surgery is part of a continuum of care for OSA that involves medical, pharmacologic, and behavioral therapy. Upper airway surgery for OSA may not alter arousal threshold, loop gain, or muscle tone. It can, however, significantly change the critical negative closing pressure. This is the same mechanism of action as PAP or OAT. The updated surgical algorithm adds precision in three areas: (1) patient selection, (2) identification of previously unaddressed anatomic phenotypes, and (3) surgical techniques (**2**).

Multilevel surgery

Patient with OSA could have multiple locations of collapse in upper and lower pharyngeal tracts. Those patients would benefit from multilevel surgery. DISE is now a standard procedure during the presurgical evaluation which gives the surgeon personalized anatomical information. A combination of multilevel procedures improved the outcome compare to single-site procedure (**3).**

In a meta-analysis that used 49 multilevel surgery articles showed success rate of 66.4% for mixed multilevel surgeries (reduction in the AHI of 50% or more and an AHI of less than 20) (**4).**

Riley et al. (5) reported their surgical experience, outlining a multilevel concept. Each patient was classified as having single-level obstruction involving the oropharynx only, type 1, or the hypopharynx only, type 3. Multilevel obstruction was identified as type 2 and implied a combination of oropharyngeal and hypopharyngeal obstruction. Of the 239 patients, 93.3% (223 patients) were identified as having multilevel obstruction, type 2. Only 16 patients (6.7%) had single-level obstruction.

Classifications of Multilevel Surgery

Published papers on apnea-hypopnea index outcomes of multilevel surgery of the upper airway for OSA can be divided into 4 groups (**6):**

1. The most commonly performed multilevel approach includes a UPPP/modified UPPP as a basic technique with a second procedure designed to improve the hypopharyngeal airway. Most commonly, this includes genioglossus advancement, thyrohyoid suspension, radiofrequency tissue volume reduction/ablation of the tongue base, tongue base resection with the assistance of transoral coblation or robotic surgery, and in some cases tongue base suspension. The success rate for these procedures has been reported to be between 20 and 100%.

2. The second group of OSA patients studied who have undergone multilevel treatment include those who have had more invasive and more radical hypopharyngeal surgery, such as open tongue base resection. Because of the aggressive nature of these procedures, some of these patients would have temporary tracheotomy and require significant hospitalization. There was also significant postoperative morbidity. The success rate in this group varied between 44 and 100%.

3. The third group of multilevel surgery for OSA included those patients undergoing bimaxillary advancement, which itself is a multilevel treatment. Many of these patients had undergone a staged surgery often with UPPP and genioglossus advancement as their primary procedure. The success rate of this group was 86.0% (**7).**

4. The fourth group is multilevel minimally invasive techniques for OSA. **Steward (8**) studied 22 patients who underwent combined radiofrequency reduction of the palate and the base of tongue and reported a success rate of 59%. **Fischer et al. (9)** presented a similar study on multilevel minimally invasive surgery with radiofrequency on the palate, tonsils and tongue base for 15 OSA patients with a success rate of 33%. **Stuck et al. (10**) published their results with radiofrequency on the palate and base of the tongue for 18 OSA patients with mild/moderate disease with a success rate of 44%. In a study presented minimally invasive single-stage multilevel surgery (MISS MLS) for patients with OSA. Their patients had undergone 3-level treatment that included nasal surgery, palatal stiffening by a palatal implant technique, and radiofrequency volume reduction of the tongue base with a minimum follow-up of 6 months. Classical success was achieved in 54 out of 122 patients (47.5%). The snoring severity improved (reduced by at least 50%) in 77.9% of patients (**6)**. **Ceylan et al. (11)** studied 26 OSA patients who underwent combined radiofrequency reduction of the palate and the base of tongue and reported a success rate of 53.8%. **Neruntarat and Chantapant (12**) also investigated 72 patients who underwent combined radiofrequency reduction of the palate and the base of tongue, and reported a success rate of 55.6%. A study further studied the effects of MISS MLS on Asian patients, finding a surgical response rate of 46.8% and classical success rate of only 14.9%. Their results show the improvement of the 2 relevant clinical outcomes in snoring severity and daytime sleepiness after MISS MLS for OSA patients, but the limited effects on the polysomnographic parameters in the Asian population (**13)**.

SURIGICAL PROCEDURES FOR OSA: ORGANIZED BY SITE

Intranasal surgery: septoplasty, turbinoplasty, nasal valve surgery

Nasal breathing is an important factor for sleep quality, and nasal obstruction does contribute to the pathogenesis of OSA. Septal deviation, turbinate hypertrophy, and valve dysfunction can result in increased nasal resistance and subsequent mouth breathing. Increased nasal resistance leads to downstream inspiratory collapse of the oropharynx or hypopharynx in susceptible OSA patients **(1).**

Mouth breathing can also cause posterior displacement of the base of the tongue and consequent narrowing of the hypopharyngeal airway. Nasal surgery including septoplasty, turbinoplasty, or valve reconstruction can restore nasal airway patency and reduce nasal resistance and mouth breathing. Although nasal surgery alone shows limited efficacy in terms of AHI, it improves sleep quality, OSA-related sleep symptoms, and PAP compliance. Nasal surgery is important in the multilevel treatment plan for OSA (**14).**

Nasal floor expansion: distraction osteogenesis maxillary expansion

Expansion of the adult nasal floor is useful for OSA patients who present with narrow and high-arch maxilla. Patients with this phenotype tend struggle with both nasal obstruction and lack of intraoral volume for the tongue during sleep. Maxillary expansion directed at the nasal floor by way of distraction osteogenesis with maxillary expansion (distraction osteogenesis maxillary expansion (DOME)) has shown promise (**15**).

Minimally invasive osteotomies can be made at the LeFort I level via an intranasal incision. An expander is anchored to the roof of maxilla intraorally. The patient turns the expander once a day, which translates to an expansion of 0.025 mm. This generally results in 8 to 10 mm of widened nasal floor at the INV in a month (Fig. 1). Orthodontic treatment restores the occlusion. Conceptually similar to pediatric rapid maxillary expansion, DOME effectively addresses the same anatomic phenotype in adults (**16**).

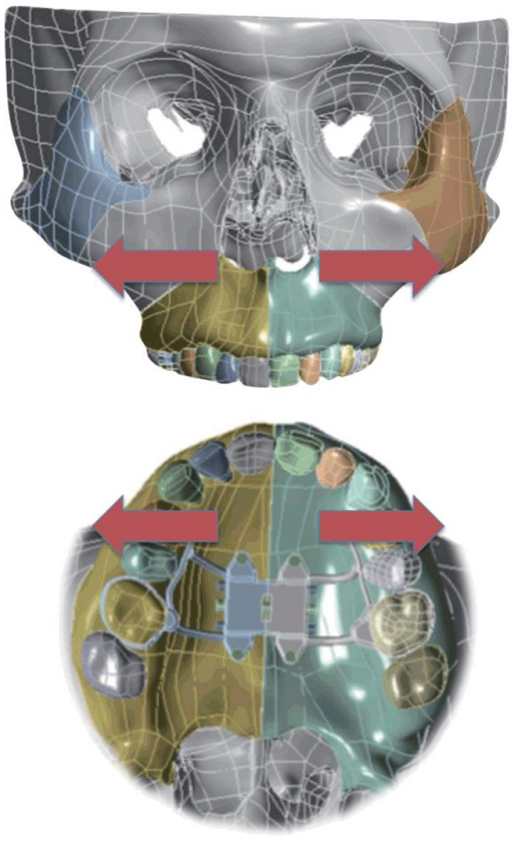

Figure 1. Distraction Osteogenesis Maxillary Expansion: maxillary expansion results in widening of nasal floor and internal nasal valve **(1).**

Oropharynx: uvulopalatopharyngoplasty

Uvulopalatopharyngoplasty (UPPP) remains the most commonly performed sleep surgical procedure worldwide. Most surgeons specialized in OSA have stopped performing earlier methods of UPPP, which tend to be ablative in nature including resection of the uvula. This is particularly true in procedures such as the laser-assisted UPPP which worsens AHI in 44% of patients based on meta-analysis. Isolated soft palate surgery has the highest success rate in Friedman stage I patients. In clinical practice, various forms of UPPP are often performed as part of multi-level surgery to maximize surgical success (**17).**

In the Riley-Powell sleep surgery algorithm, uvulopalatal flap is part of multi-level surgery with GA during phase 1. The uvulopalatal flap was designed as a reversible soft palate procedure in the event of velopharyngeal insufficiency. Most forms of contemporary UPPP focus on palatal muscle expansion and stabilization with targeted vectors during suturing (**18).**

Various techniques of palatopharyngoplasty such as lateral pharyngoplasty, expansion sphincter pharyngoplasty, and transpalatal advancement pharyngoplasty have been introduced to resolve the limitations of classic UPPP. Collectively, they have shown more successful outcomes than the classic UPPP. Sleep surgeons can individualize the options according to the pattern of collapse. For example, lateral pharyngoplasty, expansion sphincter pharyngoplasty, or similar procedures can be applied to lateral pharyngeal collapse, while transpalatal advancement pharyngoplasty can be utilized in anteroposterior narrowing **(19).**

An indication for isolated UPPP is part of a phased approach towards UAS. CCC of the soft palate (velum) seen during DISE is an exclusion criteria for UAS, palatopharyngoplasty can reverse this collapse pattern and increase candidacy for UAS **(20).**

Tongue base: lingual tonsillectomy, transoral robotic surgery

Untreated retrolingual obstruction is well recognized as a major cause of surgical failure. Removal of the lingual tonsils and base of tongue fat may involve the use of coblation, laser, or robotic assistance per surgeon preference. The removal of tissue in this area can be supplemented by an anterior anchorage of the epiglottis to the base of tongue for epiglottis collapse. With high quality optics for improved visualization and instrumentation, robotics was adapted and introduced to target the posterior tongue (**21).**

While transoral robotic surgery (TORS) offers unparalleled visualization, the use of multi-armed robots originally designed for the abdominal cavity can be cumbersome for the upper airway. Results for the use of TORS as part of a multilevel surgical approach for OSA are promising for select patients. Success rate of TORS was higher than 75% in non-obese patients and 50% in obese patients with OSA (**22).**

The cost and morbidity may be greater than with other techniques offsetting its advantages in visualization and precision. On comparing the surgical outcomes between TORS (n=820) and coblation (n=262), the mean rate of failure was found to be 34.4% in TORS and 38.5% in the coblation group. The postoperative complication rates were 21.3% and 8.4%. The advent of single port robot system which is designed for single cavity operative sites is promising. Augmented reality assisted TORS using a single-port robot will reduce morbidity such as bleeding and increase precision in distinguishing fat from muscle (**23).**

Tongue muscle strengthening: genioglossus advancement

Classic GA was designed by Powell and Riley as part of phase 1 algorithm. GA is usually performed in conjunction with other procedures (UPPP, MMA). The genioglossus muscle, a powerful dilator muscle of the upper airway, is attached to the genial tubercles. In advancing the genial tubercles, the genioglossus muscle strengthens over time and allows greater tongue advancement during sleep. With the wide availability of CT scan, virtual surgical planning and osteotomy guides allow contemporary GA to be considerably more precise (Fig. 2). GA and genioplasty can often be performed in conjunction to improve facial balance in retrognathic patients.This combination also exerts strengthening effects on suprahyoid muscles **(24)**.

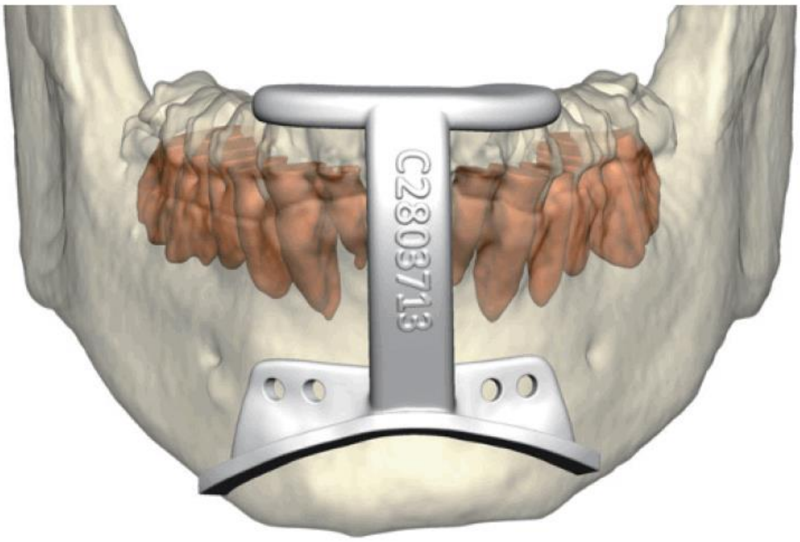

Figure 2. Virtual surgical planning of genioglossus advancement: the osteotomy guide is designed to capture the genial tubercle **(1).**

Tongue: upper airway stimulation

At the time of publication, there is only one Food and Drug Administration-approved UAS device (Inspire Medical Systems, Maple Grove, MN, USA) for OSA. It generates a unilateral respiration-synchronized stimulation of the medial hypoglossal nerve branches and C1 nerve, leading to tongue stiffening and protrusion during sleep via the genioglossus and geniohyoid muscles (Fig. 3). The hypoglossal nerve (CN XII) innervates both the tongue protrusor (genioglossus) and retrusor (styloglossus and hyoglossus) muscles through its medial and lateral divisions. Selective stimulation of the protrusor muscles leads to anterior movement of the tongue, resulting in increased airflow and reduced pharyngeal collapse during sleep. Selective stimulation of the deep and horizontally oriented genioglossus fibers results in curling and stiffening of the tongue, further expanding the upper airway (**25).**

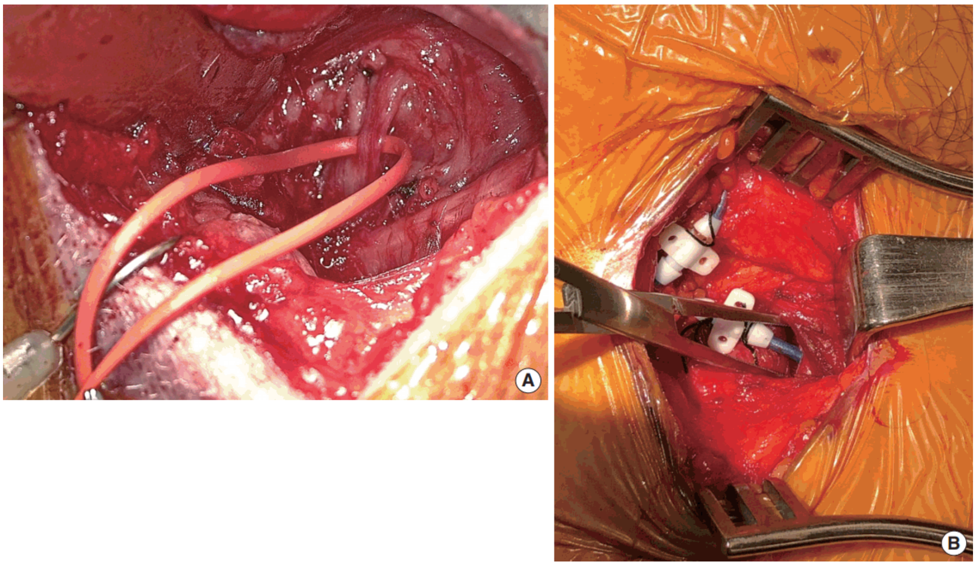

Figure 3. Upper airway stimulation (UAS): the medial branch of hypoglossal nerve is identified (A), sensing lead is placed between internal and external intercostal muscles (B) **(1).**

The current selection criteria requires DISE to rule out CCC of the velum. There is a body mass index (BMI) requirement of 32 kg/m^2 and below, and an AHI range from 15 to 65. There is a 25% cutoff for central apneas. Implanted patients undergo inlab titration of UAS approximately 2 months after implantation **(1).**

The Stimulation Therapy for Apnea Reduction (STAR) trial found UAS to be successful with a median decrease of 68% in AHI. Recent meta-analyses show that UAS is a safe and effective for selected patients with moderate to severe OSA. A study including 102 patients revealed that 22.6% of the patients used UAS therapy for less than 4 hours per night, 77.4% for 4 hours or more per night, and 55.7% of the patients for more than 6 hours per night. UAS can improve AHI as well as sleep architecture in responders. Arousal index and N1 sleep were reduced while time spent in N2 and slow wave sleep increased after UAS. There are no significant changes to rapid eye movement (REM) sleep (**26).**

Total upper airway: maxillomandibular advancement

MMA is pioneered by Riley and Powell at Stanford Hospital in the late 1980's, and addresses the entire upper airway that can contribute to OSA. It remains one of the most effective surgical intervention for patients with OSA, and has compared favorably to continuous positive airway pressure (CPAP) in a variety of studies including a prospective, randomized controlled trial. MMA involves osteotomies of the maxilla and mandible, followed by their advancement that is frequently accompanied with counterclockwise rotation (Fig. 4). The net effect includes greater volume for intraoral soft tissue structures and stability of the upper airway dilator muscles (**27).**

Generally, indications for MMA are : (1) moderate to severe OSA with our without history of phase 1 surgery, (2) OSA of all severity if there is comorbid dentofacial deformity, and (3) concentric and lateral pharyngeal wall collapse seen with DISE. Age of patient and severity of OSA have not been shown to impact the technical aspects of MMA in a high volume center (**28).**

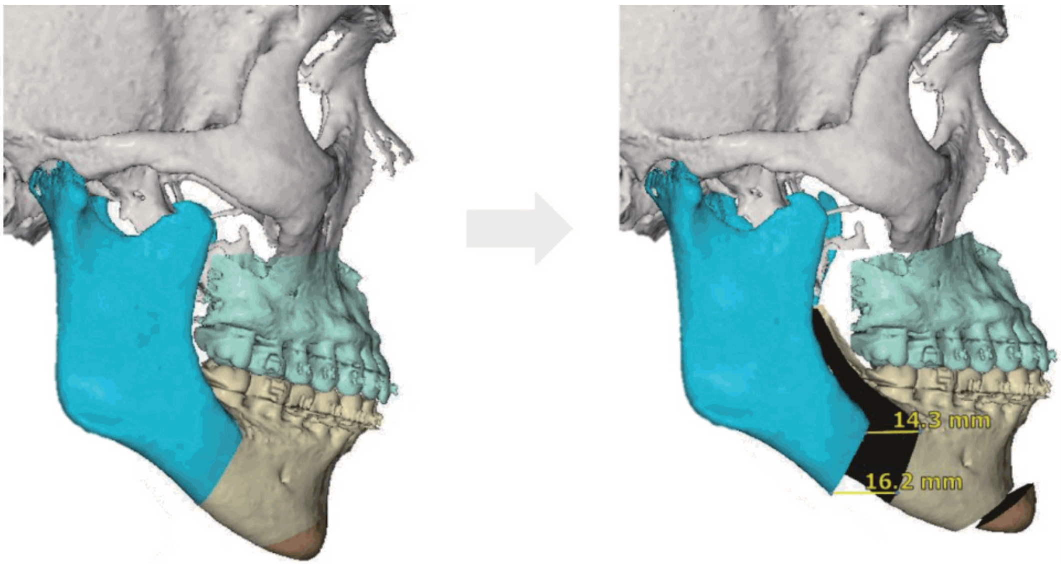

Figure 4. Counterclockwise maxillomandibular advancement allows a greater advancement of mandible than maxilla, to maximize airway and facial esthetics **(1).**

Meta-analysis by **Holty and Guilleminault** (7) examined 22 studies involving 627 patients who underwent MMA, reporting mean AHI decrease from 63.9 to 9.5 events per hour. The authors defined surgical success with the Sher criteria: a minimum of 50% reduction with a final AHI less than 20. The surgical success rate was 86.0% and the cure rate (AHI <5) was 43.2%. The predictive factors for surgical success were younger age, lower BMI, and greater degree of maxillary advancement. The major and minor complication rates were 1.0% and 3.1%, respectively. **Zaghi et al. (29)** updated the meta-analsysis with 45 studies and 528 patients reporting success and cure rates of 85.5% and 38%, respectively. In 40 patients who underwent MMA with average follow-up of 4.2 years (range, 1 to 12 years), 36 patients (90%) maintained a significant reduction in respiratory disturbance index from 71.2 to 7.6 events per hour with improvement in daytime sleepiness. In another study with mean follow-up of 12.5 years, surgical success rate maintained at 100% in patients less than 45 years old, and who had BMI less than 25 kg/m^2 (**30**).

Beyond the AHI, MMA has shown normalization of sleep architecture (increase in REM sleep and decrease in wakefulness after sleep onset when compared to age-matched healthy controls. It has also shown improvements in multiple health-related and functional outcomes (**31).**

SURGICAL ALGORITHM: PATIENT-CENTERED, PATIENT FIRST

Surgical algorithm for OSA considers anatomic abnormality, disease severity, and patient preference. The balance between these three factors and morbidity of surgery must be emphasized. **Riley et al. (5)** developed the original sleep surgery algorithm where soft tissue and skeletal framework were targets for intervention.

The updated algorithm reflects the contemporary needs of improved precision on: (1) patient phenotyping, (2) new procedures to address distinct phenotypes, and (3) improved methods for previously established operations (**27**). The updated algorithm is shown in Fig. 5.

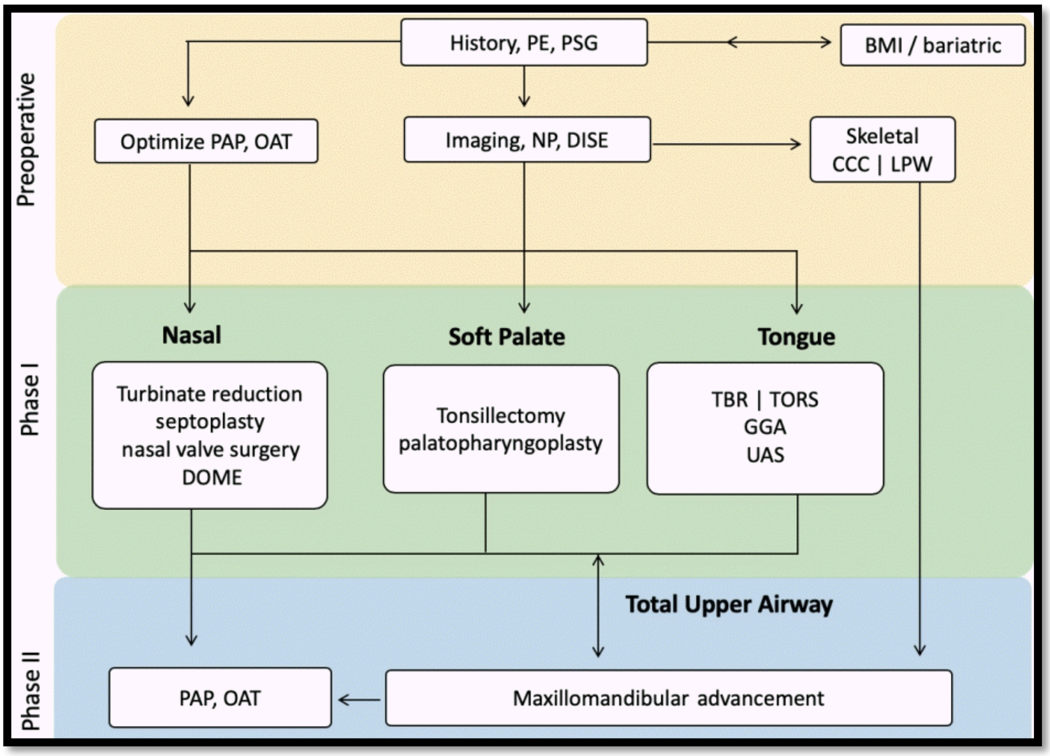

Figure 5. Updated Stanford sleep surgery algorithm **(1).** PE, physical examination; PSG, polysomnography; BMI, body mass index; PAP, positive airway pressure; OAT, oral appliance therapy; NP, nasopharyngoscopy; DISE, drug-induced sedation (sleep) endoscopy; CCC, complete concentric collapse; LPW, lateral pharyngeal wall; DOME, distraction osteogenesis maxillary expansion; TBR, tongue base reduction; TORS, transoral robotic surgery; GGA, genioglossus advancement; UAS, upper airway stimulation.

In clinic, after a thorough history, physical exam, review of PSG, and nasopharyngoscopy, the first decision is made regarding optimization of PAP or OAT use. Of note, the efficacy of upper airway surgery for OSA begins to drop as BMI increases. Bariatric surgical evaluation and treatment should precede upper airway surgery in select candidates. Use of imaging or DISE to help determine treatment course is made judiciously on an individual basis, as they are supplemental tools **(1).**

MMA and UAS have been highly effective surgical options for the treatment of OSA. Both have shown predictably high success rates with low morbidity. They differ in strengths and limitations, and may complement each other. DISE is currently required to rule out CCC of the velum for UAS. Concentric collapse and lateral pharyngeal wall collapse from DISE are associated with low success rate of soft tissue surgery (**32**). MMA is more reliable in reversing these collapse patterns. MMA can also be a first-line consideration for patients with any degree of OSA with dentofacial deformity. If MMA is performed first, the patient is still eligible, and may need, phase 1 procedures. UAS or PAP following MMA relapse are safe options especially in patients with advanced age **(33).**

Outcomes of Multilevel Obstructive Sleep Apnea Surgery

In order to apply evidence-based medicine criteria to the question of whether multilevel surgery of the upper airway may benefit patients with OSA, a study performed a systematic review of all published series focusing on the subjective and objective outcomes of OSA patients treated with multilevel surgery in 2008. 49 multilevel OSA surgery articles were identified. There were 1,978 patients included in this analysis. There were significant changes in the apnea index, apnea-hypopnea index, percent of rapid eye movement sleep, minimal saturation of oxygen, snoring 0–10 visual analog scale, Epworth Sleepiness Scale, and quality of life. The original reported success rate in the included literature was 64.5%. However, the definition of success used by the authors was not consistent. Therefore, a meta-analysis was performed with the success rate defined as the postoperative apnea-hypopnea index reduced by >50% and < 20 events/h, which is a commonly used criterion for success. The recalculated success rate was 66.4%. The overall complications were minor with a rate of 14.6% (**4).**

In the last decade, several surgical advances have been made in the management of OSA. There have been many new techniques or modifications of traditional surgical procedures with reported more favorable outcomes. The relatively new modifications included Z-palatopharyngoplasty, lateral pharyngoplasty, expansion sphincter pharyngoplasty, relocation pharyngoplasty, transoral endoscopic coblator tongue base resection, transoral robotic OSA surgery, and many others. Since the patient load has nearly doubled with many new publications, it is important to re assess the published success rate (**6).**

Single- versus Multistage Surgery in Multilevel OSA Treatment

Multilevel treatment can be performed in a single stage or in multiple stages. Most studies revealed that single-stage surgery at multiple levels did not increase postoperative complications; however, these studies were too underpowered to claim equivalence with confidence (**6**).

A large cohort study showed an elevated risk of serious complication when UPPP was combined with a concurrent nonnasal procedure compared to UPPP alone (adjusted risk ratio 4.8, 95% confidence interval 2.5–9.1), but no elevated risk when UPPP was combined with a nasal procedure. This study did not examine the cumulative risk of staged surgery. Single-stage multilevel surgery can lower total hospitalization expenses when compared to multi-staged surgery (**34**). **Kieff and Busaba (35**) reported the safety of same-day or overnight discharge and concluded that sameday discharge for patients who have undergone combined nasal and palatal surgery for OSA is relatively safe in selected cases when significant comorbid diseases are not present.

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