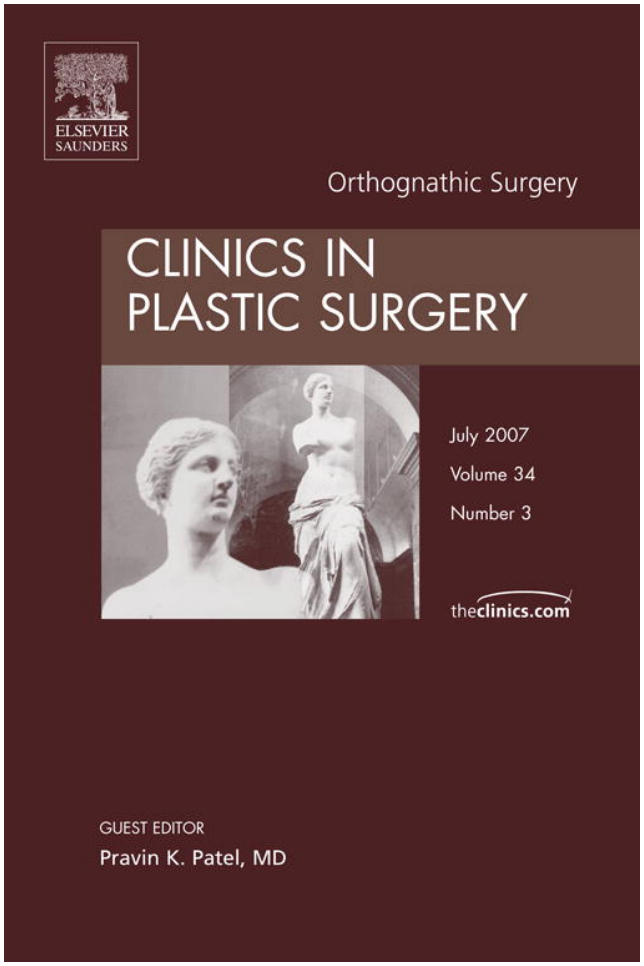

ELSEVIER SAUNDERS

CLINICS IN PLASTIC SURGERY

Clin Plastic Surg 34 (2007) 565–573

Facial Skeletal Surgery in the Management of Adult Obstructive Sleep Apnea Syndrome

Jose E. Barrera, MD, FACS*, Nelson B. Powell, MD, DDS, FACS, Robert W. Riley, MD, DDS, FACS

Sleep disordered breathing (SDB) is a spectrum of syndromes comprising snoring, upper airway resistance syndrome (UARS), and obstructive sleep apnea (OSA). OSA is a syndrome, not a disease, and the specific etiology is unknown; however, it is primarily secondary to anatomic upper airway narrowing during sleep, and an as yet unidentified central nervous system component. Obstructive sleep apnea syndrome (OSAS) consists of periods of apneas (cessation of airflow at the nose or mouth for greater than 10 seconds) and hypopneas (reduced respiration with desaturation terminated by arousal). In general, OSA can be defined by the number of apneas and hypopneas per hour, or apnea-hypopnea index (AHI). Mild OSA is defined as an AHI greater than 5 and less than 15, but with symptoms of sleepiness. Moderate OSA is an AHI greater than 15 and less than 30, and severe OSA is an AHI greater than 30.

The prevalence of OSA was reported to be 24% in males and 9% in females in an epidemiologic study by attended polysomogram in 602 undiagnosed state employees [1]. Most patients fail to be diagnosed; in fact, 93% of females and 82% of males who have moderate to severe OSA have not been identified [2].

The profound effects of SDB upon the cardiovascular and respiratory systems and neurocognitive function have been documented. The Sleep Heart Health Study and the Wisconsin Sleep Cohort [3,4] have demonstrated a strong association between SDB and hypertension. Patients who have an AHI greater than 15 have a 2.89 fold greater chance of developing hypertension [5] than those who do not have such an AHI. In patients who have an AHI greater than 11, there is a 2.38 relative risk for congestive heart failure, and a 1.58 risk for cerebrovascular disease [6–8].

Before planning surgical interventions to the upper airway for OSAS, the surgeon needs familiarity with the rationale and indications for such surgery. In addition, it is essential that the surgeon have

Division of Otolaryngology, Head and Neck Surgery, Stanford Hospital and Clinics, 801 Welch Road, 2nd Floor, MC 5739, Stanford, CA 94305, USA
* Corresponding author.
E-mail address: Jbarrera@ohns.stanford.edu (J.E. Barrera).

0094-1298/07/$ – see front matter
doi:10.1016/j.cps.2007.04.010
plasticsurgery.theclinics.com

a basic understanding of the syndrome and the evaluations that are needed to properly plan diagnostic and therapeutic interventions. Hence, a brief summary of some of the essential workup is presented before discussing actual surgical treatments.

Patient evaluation

A complete history must be taken from the patient. It can be broken into behavioral quality of life issues and pathophysiologic derangement. Patients who have OSA suffer from quality of life issues, including nighttime complaints of snoring, unusual movement, insomnia, hypersomnia, and sexual dysfunction. In addition, daytime dysfunction, including sleepiness, automatic behavior, morning headache, learning and memory problems, and depression, are common.

Patients who have OSA most often complain of excessive daytime sleepiness (EDS). The patients may experience serious social, economic, and emotional problems from the EDS associated with this disorder. The uncontrollable desire to sleep may predispose the patients to safety-sensitive occupational or automobile accidents.

Almost all patients or their bed partners give a chronic history of heavy, loud snoring. The snoring is produced from the passage of air through the oropharynx causing vibrations of the soft palate. Typically the snoring is interrupted by periodic apneic episodes that may last 30 to 90 seconds. A loud snort followed by a hyperventilation usually signals an end to the apneic episode.

Other common presenting complaints are morning headaches and nausea that result from the hypercarbia that develops with hypoventilatory episodes. Depression, personality changes, and intellectual deterioration may also develop.

Pathophysiologic abnormalities include systemic hypertension, which is a common finding in OSA, and may be related to abnormal sympathetic tone during sleep, with subsequent catecholamine release triggered by the systemic hypoxemia combined with marked negative intrathorasic pressure changes. In more severe cases, pulmonary hypertension, polycythemia, and cor pulmonale may develop and become life-threatening.

Sinus dysrhythmia is commonly associated with the apneic episodes. Bradycardia may be directly proportional to the severity of oxygen desaturation. The development of severe and life-threatening medical complications from the apneic events clearly depends on the frequency, duration, and degree of hypoxemia and associated hypertensive response.

Physical examination

A complete physical examination and flexible nasopharyngoscopy are necessary to help define the patient's anatomy. The presence of other potential causes, such as neoplastic disease and congenital anomalies, should be ruled out. Comorbidities are common in OSA, and should be carefully evaluated before any surgical approach. Laboratory data, including complete blood count and comprehensive metabolic panel, are obtained.

A common feature of OSA is obesity. The increased body weight correlates with increased frequency of apnea and the severity of hypoxemia; however, the morbidly obese, somnolent, hyperventilating patient who has cor pulmonale represents only a small number of sleep apnea patients.

Obstruction can occur at a number of points in the airway. Physical examination of these patients may reveal hypertrophy of the adenoids and tonsils, retrognathia, micrognathia, macroglossia, deviation of the nasal septum, turbinate hypertrophy, a thick short neck, or tumors in the nasopharynx or hypopharynx. Both primary and secondary medical conditions are associated with OSA, owing to their effects on the upper airway anatomy. These may include temporomandibular joint disorders, myxedema, goiter, acromegaly, and lymphoma. In addition, most patients who have classic OSA have no identifiable craniofacial anomaly.

Fiberoptic nasopharyngoscopy is used to identify obstruction at the nasopharynx, oropharynx, hypopharynx, and to rule out laryngeal anomalies. It can help estimate the degree of lateral wall collapse, palatal narrowing, and tongue base obstruction. OSA is largely considered a syndrome presenting with diffuse and dynamic obstruction. To simplify the presentation, Fujita developed a classification system to describe the site of obstruction. A Fujita Type I obstruction is determined to be palatal obstruction only, II presents as a combined palatal and tongue base obstruction, and III as a tongue base obstruction pattern only. Fiberoptic evaluation aids in elucidating these obstructive patterns.

Cephalometric evaluation is a simple way to evaluate individual patient upper airway obstruction. Cephalometric evaluation has long been used in evaluation of the airway in OSA. The metrics used for evaluation are similar to metrics described for orthognathic surgery, with particular attention to the posterior airway space (PAS). These metrics are used to evaluate preoperative obstruction and follow postoperative results. It is recommended that this two-dimensional radiograph be supplemented with a three-dimensional fiberoptic nasopharyngoscopy to evaluate the airway. At the

authors' institution, the most consistent finding is a narrowed PAS and low hyoid position [4,9,10].

The definitive objective test is a study during sleep. The gold standard at present is an attended polysomnographic evaluation. This Level I study assesses the cardiorespiratory system, revealing oxygenation information, and records electroencephalogram (EEG), electro-oculogram (EOG), and electromyogram (EMG). It reveals sleep stage information and estimates the percentage of apnea, hypopneas, and respiratory-related events during sleep. Ambulatory studies are estimated as Level III, and do not determine sleep stage data.

Nonsurgical management of obstructive sleep apnea

There are several medical treatment options for OSA, including weight loss, improved sleep hygiene, oral appliance, and continuous positive airway pressure (CPAP)/bilevel positive airway pressure (BiPAP). Two treatment modalities are reviewed here: weight loss and CPAP.

Weight loss decreases comorbid risks and is beneficial in combination with other treatment modalities. In a longitudinal study of moderate weight gain, Pepperd and colleagues found that a 10% weight gain predicted a 32% increase in AHI, whereas a 10% weight loss predicted a 26% decrease in AHI. Strategies for weight loss include combined dietary, exercise, and behavior therapy.

CPAP, a noninvasive methodology, is currently the mainstay of medical management of OSAS. CPAP has been shown to improve ambulatory blood pressure and has reduced the cardiovascular risk in men who have OSA with an AHI greater than 30. In addition, CPAP appears to be protective. CPAP has been shown to improve measures of SDB, including apnea, AHI, and respiratory disturbance index (RDI). It has been shown to improve insulin sensitivity, and reduce the risk of automobile accidents. CPAP is covered by Medicare if AHI is greater than 15 or AHI is greater than 5 with EDS, impaired cognition, hypertension, or history of ischemic heart disease or stroke. If tolerated, CPAP or BiPAP offers the best form of treatment, but does not offer a chance for cure. In addition, one night off CPAP reverses all the gains derived from sleeping with the device [11].

Surgical management of obstructive sleep apnea

A contemporary two-phase surgical approach for OSAS treatment has been developed to limit overoperating and to decrease risks of surgery. It is important to note that if this phased protocol is used, the patient and referring physician must understand that both phases may be necessary; the protocol was not intended to be a single-phase procedure. It is necessary to re-evaluate the patient at 4 to 6 months after Phase I with a polysomnogram. If the patient is controlled, no further treatment is needed. If incompletely treated, then Phase II is appropriate. Phases are outlined below:

Phase I
Nasal reconstruction
uvulopalatopharyngoplasty (UPPP)
Genioglossus/hyoid
Temperature controlled tongue base radiofrequency (TCTBRF)
Phase II (for incomplete treatment of Phase I)
Bimaxillary advancement (maxillomandibular advancement [MMA]) or
Tongue reduction

The first phase is the most conservative approach, and addresses palatal and tongue base obstruction without movement of the jaw or teeth. Responders are defined below:

RDI $\leq$20 and/or at least a reduction of 50%
Oxygen saturation $\geq$90%
Normalization of sleep architecture
Resolution of EDS
Equivalent to CPAP on second titration night

It should be emphasized that improved surgical success depends on optimizing the soft-tissue or primarily Phase I protocol before beginning Phase II. A multidisciplinary approach consisting of otolaryngology-head and neck surgery (OHNS), and the services of a sleep medicine specialist, and skilled skeletal surgeons (ie, OHNS, plastic surgeons, or oral and maxillofacial surgeons [OMFS]) is recommended in treating the patient who has OSAS.

Tracheotomy or bypass surgery (bypasses the main obstruction) was the first described treatment of OSA, and still remains a viable option for severe OSA. It provides immediate resolution of obstructive breathing during sleep in most subjects. It is indicated where an emergent airway is necessary, or where there is neither the specialized equipment nor the surgical expertise to offer an alternative. It is also indicated for the morbidly obese patient who has a body mass index (BMI) greater than 33 kg/m^2), severe hypoxemia ($Sa0_2 \leq 70$), severe arrhythmia, asystole, premature ventricle contractions (PVCs), uncontrolled hypertension, and where surgery to alleviate upper airway obstruction may compromise the airway secondary to edema or drug therapy, and CPAP is not available or tolerated by the patient. In reality, tracheotomy is usually, but not always, poorly tolerated or accepted. This is especially true now, because nasal CPAP has been

used so successfully for severe OSAS that tracheotomy has taken a second position in the treatment of OSAS.

Nasal obstruction is often encountered in the form of septal deviation, turbinate hypertrophy, or nasal valve stenosis. Nasal reconstruction may improve CPAP tolerance and ensure nasal airflow during sleep. Reconstruction may consist of septoplasty for deviation repair, turbinate reduction using radiofrequency, or submucous resection of the turbinates. In addition, external or internal valve repair may be warranted.

Retropalatal obstruction is dealt with UPPP. UPPP with tonsillectomy was introduced by Fujita and colleagues in 1979. Many modifications have been published. The basic procedure involves palate shortening with closure mucosal incisions, tonsillectomy, and lateral pharyngoplasty (Fig. 1). UPPP results in symptomatic improvement in the patient and eliminates habitual snoring in almost all cases; however, reports show that significant objective improvement on the postoperative polysomnogram ranges only from 41% to 66% [12]. This procedure only eliminates the obstruction at the level of the soft palate, and does not address obstructions occurring in the hypopharyngeal and base of tongue areas. Most patients have more than one site of obstruction. If UPPP is performed when the presurgical evaluation demonstrates obstruction localized to the soft palate-tonsil area, then the success rate of the surgical procedure approaches 90% in treating OSA [10].

Hypopharyngeal obstruction is treated with tracheostomy, genioglossal advancement (GA), or MMA. GA is a simple technique that does not move the teeth or jaw, and therefore does not effect the dental bite (Fig. 2). GA is a procedure performed as a solitary hypopharyngeal procedure or in combination with MMA. The technique places the genioglossus under tension, and this tension may be sufficient to keep the base of tongue region open during sleep. This procedure does not gain more room for the tongue, and thus must be considered a limited procedure that is dependent on the thickness of the individuals anterior mandible (mean thickness 12–18 mm). In addition, the existing laxity to the tongue during sleep is a factor on how much tension is gained when the genial

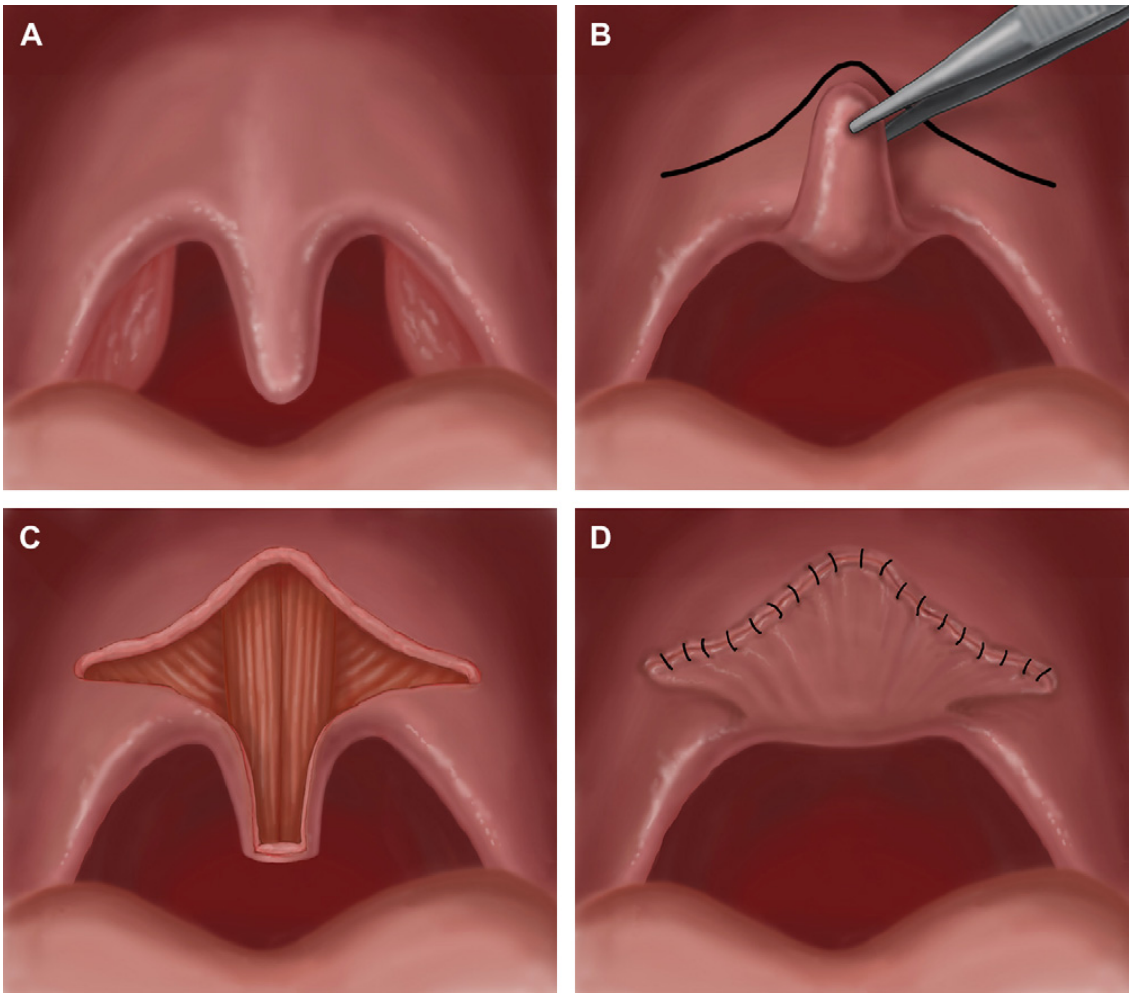

Fig. 1. Techniques used for uvulopalatal flap surgery. (*A*) Preoperative. (*B*) Post-tonsillectomy and uvular flap design. (*C*) Mucosal excision. (*D*) Trimmed and sutured flap.

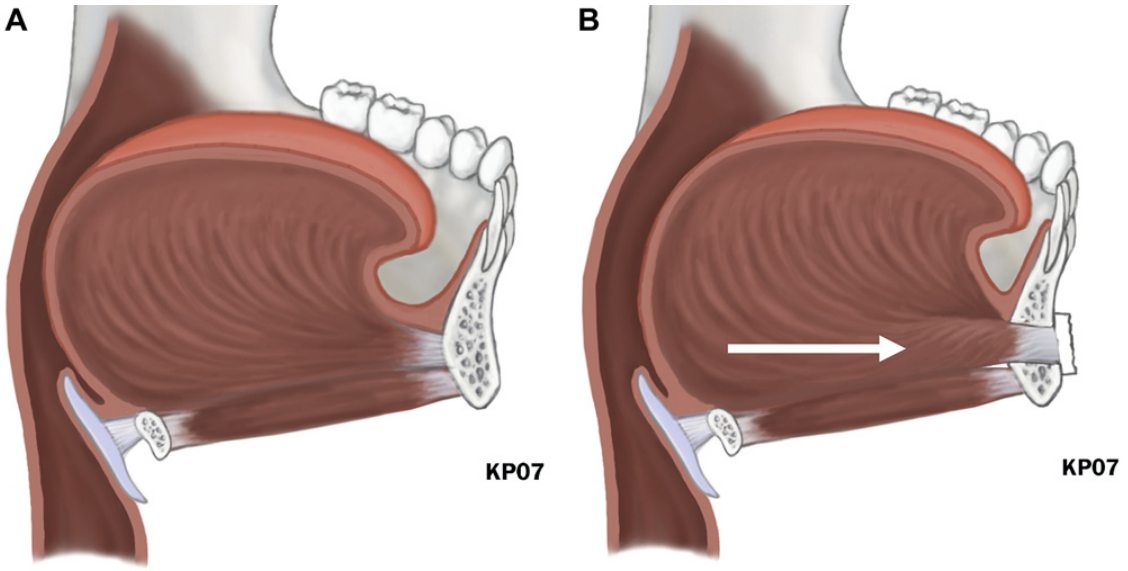

Fig. 2. Preoperative (*A*) and postoperative (*B*) saggital views of the genioglossal muscle advancement procedure used to treat hypopharyngeal obstruction in Phase I management of OSA.

tubercle is moved. In a flaccid tongue, the movement may all or partially be taken up by the advancement, and little or no improvement may be attained. Unfortunately, we have no method to predict the level of laxity on an individual basis, or the critical distance the genial tubercle needs to move for effective airway space clearance. These two factors limit our preoperative ability to accurately or consistently predict clinical outcomes. The authors' published clinical outcomes for cure rates for Phase I is 42% to 75%, depending on the severity of the disorder. Other centers have reported similar results with this procedure.

GA can be performed under sedation as a solitary procedure, or under general anesthesia in combination with other surgical procedures. First an intraoral incision is made in the gingival buccal sulcus, taking care to leave a cuff of mucosa to facilitate closure. Dissection is performed submucoperiosteal to expose the inferior border of the mandible. The location of the genial tubercle is confirmed by palpation and identified on radiographs. The osteotomy is outlined with a sagittal saw though the outer cortex. The typical outline is 10 mm × 18 mm, and centered 5 mm inferior to the root apices, and at least 8 mm above the inferior border of the mandible. A titanium screw is placed in the center of the osteotomy to control the segment prior to completely mobilizing the inner cortex with the sagittal saw. Once completed, the fragment is displaced medially to visualize the floor of the mouth and obtain hemostatsis. Electrocautery, and when indicated, Gelfoam (Pharmacia, Kalamazoo, Michigan), is directed to mandibular bleeding coming from the marrow space. The mandibular segment is then advanced and rotated. The outer cortex and marrow are removed, and the remaining inner cortex is fixated via a lag screw (see Fig. 2). A pear-shaped burr may be used to contour the fragment in order to facilitate closure. Closure is performed with absorbable suture.

Advancement genioplasty is not a recommended procedure in the treatment of OSAS. This procedure may not include the entire genial tubercle, thereby not affecting pull on the genioglossal muscle. It will likely pull the geniohyoid muscle, which may lead to an unfavorable vector on the tongue base.

Hyoid myotomy and suspension may be performed with GA to enact additional widening of the PAS. It is usually performed as a Phase I procedure or as a solitary adjunctive procedure. In addition, TCTBRF has been used as a Phase I procedure to promote tongue reduction and improve the hypopharyngeal airway.

Patients who have had incomplete response or who failed to respond to Phase I intervention may be considered for a Phase II operation or MMA. The advancement of the midface provides more room for the tongue, and sagittal split osteotomy of the mandible places additional tension on the tongue-hyoid complex.

Combined advancement of the maxilla and mandible is the most recent and efficacious surgical procedure for the treatment of OSA (Fig. 3). The surgical technique includes a standard Le Fort I osteotomy, in combination with a mandibular sagittal split osteotomy. A concomitant GA, as previously described, is recommended to improve tongue advancement. This surgery may result in some facial change, which most often may be favorable.

Several authors have described the use of MMA in treating large series of obstructive sleep apnea patients. In a series of 23 patients, Waite and colleagues performed a high sliding horizontal

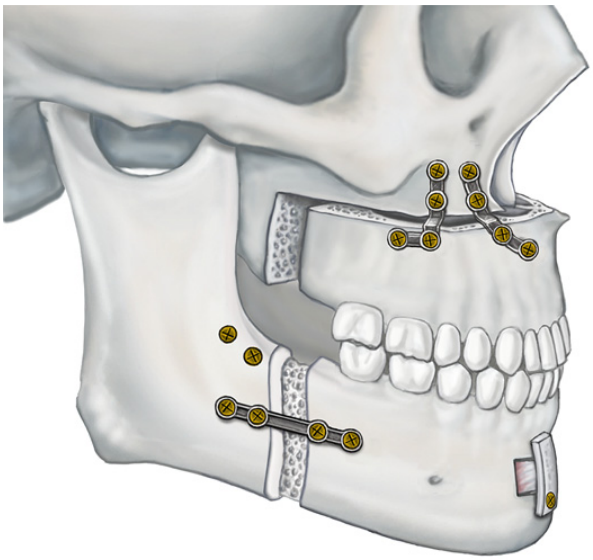

Fig. 3. Maxillo-mandibular advancement with genioglossal advancement.

geniotomy without the hyoid myotomy and suspension [13,14]. All patients were reevaluated by polysomnography at 6 weeks postoperatively. The surgical success with MMA was 65%, based on a postsurgical RDI of less than 10. A limitation of this study was that the Phase I protocol was not optimized before engaging the Phase II operation. Riley and colleagues reported the largest series of obstructive sleep apnea patients (N = 306) treated with a phased protocol [15]. Phase I consisted of UPPP and genioglossus advancement with hyoid myotomy/suspension (GAHM), resulting in a 61% success rate (n = 239). Unsuccessful Phase I patients (n = 84) and patients who had skeletal deformity (n = 7) underwent MMA. MMA yielded overall 90% or greater success, based on a postoperative RDI of less than 20, with at least a 50% reduction in the RDI if the RDI was initially less than 20 compared with the preoperative study.

The PAS consistently increases with maxillomandibular advancement; however, there may be cases in which a small gain in PAS is seen and yet improvement is realized. MMA is the most efficacious procedure for expanding the pharyngeal airway and improving or eliminating OSA. It remains the best current alternative to tracheotomy.

Indications for this procedure include altered daytime performance: neurobehavioral symptoms, RDI >20, oxygen desaturation <90%, arrhythmias (cardiovascular derangements), negative esophageal pressure (Pes), and base of tongue obstruction (Fujita Type III). The success rate of MMA appears to increase when adjunctive procedures such as UPPP, GA, TCTBRF, septoplasty, or turbinectomies, by themselves or together, are included in the treatment plan. This lends support to the theory that most obstructive sleep apnea patients have multiple levels of obstruction because of the diffuse airway involvement.

MMA is performed by first ensuring proper and safe nasal intubation with the surgical team in attendance. Arch bars are typically used to facilitate postoperative maintenance of occlusion. Orthodontic bands can be used as an alternative. The Lefort I osteotomy is performed first. The incision is made through the mucosa, and a submucoperioteal flap is elevated. Special care is taken not to injure the nasal mucosa medially. The horizontal osteotomy is placed above the root apices using a reciprocating saw. A curved osteotome is used to separate the pterygomaxillary junction, with care to preserve, if possible, the descending palatine artery. If signs of ischemia are noted, the maxilla is replaced. Aggressive advancement of 8 to 12 mm is performed. Rigid fixation is accomplished using 24 gauge wires and four titanium miniplates.

Next the sagittal split osteotomy is performed. The incision begins in the external oblique ridge and extends anteriorally to the canine. The periosteum is elevated to expose the medial and lateral surface. The lingual and neurovascular bundle are identified medially. A reciprocating saw is used to cut through the outer cortex and extend mesial to the first molar. Using a fissure burr and drill, a vertical cut is made from the inferior border of the mandible to the osteotomy. Osteotomes are used to carefully complete the split and identify the inferior alveolar nerve. Once osteotomies are made bilaterally, the mandible is advanced and brought into occlusion, using a prefabricated methylmethacrylate splint. Rigid fixation is obtained with percutaneous bicortical screws, mandibular 2.0 mm titanium plate, and cortical plate screws (see Fig. 3). Intermaxillary fixation is seldom used, but can be used at the surgeon's discretion.

Complications

Acute airway obstruction in patients who has OSA is difficult to manage, and death in the early postoperative period has been reported because of respiratory obstruction caused by pharmacologic sedation and surgical edema. Therefore, minimal use of postoperative narcotic analgesics in favor of nonnarcotic analgesics is recommended. The careful monitoring of blood pressure is important to control edema and hemorrhage. Postoperative malocclusion or malunion can be lessened by the use of rigid fixation, attention to occlusion intraoperatively, and maintenance of a soft diet for approximately 6 weeks.

Postoperative considerations: airway management (Phase I and II)

In a prospective review of 10 patients who had severe OSAS undergoing surgical treatment, patients were maintained on nasal CPAP after surgery. Patients were monitored in the intensive care unit (ICU)for the first day, and then for an additional day in the surgical ward. In spite of a mean pretreatment RDI of 87 and a mean lowest saturation (LSAT) of 51.5%, the mean postoperative LSAT during the hospital stay was 93%. Nasal CPAP protected postoperative patients who had OSAS from airway obstruction and hypoxemia [15].

Risk management protocol

The following protocol was derived after evaluating 182 consecutively treated patients who had OSAS undergoing 210 procedures [16].

1. Intraoperative airway risks can be reduced by fiberoptic intubation in patients who have increased neck circumference and skeletal deficiency. Furthermore, a preoperative fiberoptic evaluation by the surgeon can assess the upper airway for difficulty during intubation and extubation. The findings can be passed to the anesthesiologist and safeguards made.
2. Patients who have OSAS are at a significantly increased risk for hypertension. Postoperative management of hypertension must be treated initially with intravenous (IV) medication in the ICU and oral medication in the immediate recovery period.
3. Nasal CPAP improves or eliminates some of the postoperative risk of hypoxemia. Patients who have an RDI greater than 40 and an LSAT less than 80% should begin nasal CPAP at least 2 weeks before surgery, and continue nasal CPAP after surgery until polysomnography (in 6 months) is performed to document outcome. All patients, however, are encouraged to attempt nasal CPAP before and after surgery.
4. All patients are induced and intubated with the surgeons present, and an awake fiberoptic intubation is performed if there are any concerns about the airway. All patients are extubated when awake in the operating room.
5. All patients undergoing multiple procedures (UPPP and maxillofacial surgery), or single procedures in which the patient has significant coexisting medical problems (hypertension or coronary artery disease), are monitored in the ICU for the first day after surgery and then in the surgical ward. Oximetry is monitored throughout the hospital stay.
6. Patients who have nasal CPAP must use the machine during all periods of sleep after surgery. All other patients are maintained on humidified oxygen (35%) through a face tent.
7. Analgesia consists of intravenous morphine sulfate or meperidine HCl in the ICU. Intravenous narcotics are administered by a nurse in graduated doses (eg, morphine sulfate, 1 to 5 mg every 1 to 3 hours as needed) while monitoring respiratory rate. All nurses caring for patients who have OSAS have been educated regarding the mechanism of sleep apnea and the use of narcotics. Patient-controlled analgesia (PCA pumps) is not recommended. Intramuscular meperidine HCl and oxycodone elixir are used in the surgical ward. Oral hydrocodone is used after discharge.
8. Requirements for discharge are adequate oral intake of fluids, satisfactory pain control, stable or resolving surgical edema, and the use of nasal CPAP if tolerated.

Case presentation

A 51-year-old male had fatigue, snoring, and witnessed apneas. His initial BMI was 38.7 kg/m^2. Work-up included polysomnography (PSG), ECG, stress echocardiogram, and CPAP trial. ECG

Table 1: **Case presentation of patients undergoing Phase I and II**

Metric	TST (%) pre	TST % post Phase I	TST % post Phase II
Stage I	45.6	28.3	12.1
2	52.1	64.9	67.2
3	0	2.5	0.4
4	0	0	0
REM	2.3	4.3	20.4
SE %	92.5	83.9	94
AHI	93.6	62.5	4.6
LSAT	82.8 (5.4 min)	89.8 (34 sec)	85 (20 sec)
BMI (kg/m^2)	38.7	35.7	33.2

Abbreviations: AHI, apnea-hypopnea index; BMI, body mass index; LSAT, lowest saturation (during study); REM, rapid eye movement; SE, sleep efficiency; TST, total sleep time.

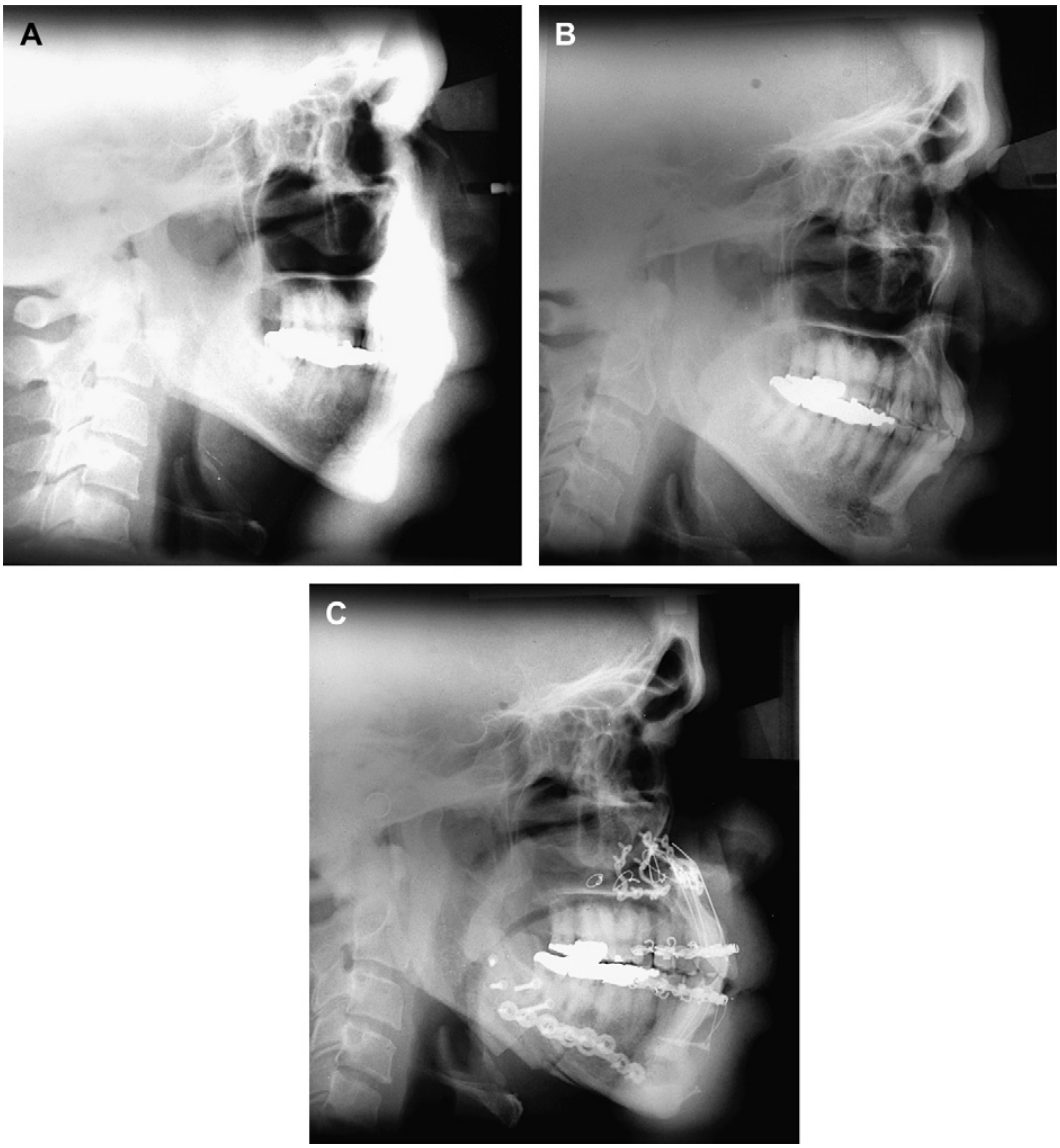

Fig. 4. Cephalometric views of case presentation: (*A*) preoperative, (*B*) post-Phase I (UPPP and GA), (*C*) post-Phase II (MMA). Note the sequential change in the posterior airway space.

revealed nonspecific T-wave changes and PVCs, and a stress echocardiogram revealed normal left ventricular function and no ischemic changes. The patient agreed to wear CPAP, but this was not a viable long-term solution. Sleep stage metric, AHI, LSAT, BMI, and sleep efficiency (SE) data preoperative, post-Phase I (UPPP and GA), and post-Phase II are shown in Table 1. The patient demonstrated significant improvement after Phase I and complete cure after Phase II. Serial cephalometric radiographs demonstrate the change in the airway space (Fig. 4). The preoperative PSG for CPAP titration was compared to the postoperative PSG and was similar.

Summary

Obstructive sleep apnea remains a significant public health problem because of its neurocognitive sequelae. Additionally, with persistent obstruction it has an impact on the cardiovascular system, leading to hypertension and cardiac failure as one of its causative or comorbid factors. For the surgeon managing OSA, there is a stepwise sequence of surgical procedures, from improving nasal airflow to facial skeletal maxillary-mandibular advancement, with the cumulative goal of volumetrically increasing the retropharyngeal airway space. Familiarity with conventional orthognathic principles is essential in achieving this goal.

References

[1] Young T, Palta M, Dempsey J, et al. The occurrence of SDB among middle-aged adults. N Engl J Med 1993;328:1230–5.
[2] Young T, Evans L, Finn L, et al. Estimation of the clinically diagnosed proportion of sleep apnea syndrome in middle aged men and women. Sleep 1997;20:705–6.
[3] Nieto JF, Young TB, Lind BK, et al. Association of SDB, sleep apnea, and hypertension in a large

community based study. JAMA 2000;283: 1829–36.
[4] Peppard PE, Young T, Palta M, et al. Prospective study of the association of SDB and hypertension. N Engl J Med 2000;342:1378–84.
[5] Somers VK, Dyken ME, Clary MP, et al. Sympathetic neural mechanisms in OSA. J Clin Invest 1995;96:1897–904.
[6] Shahar E, Whitney CW, Redline S, et al. SDB and cardiovascular disease: cross-sectional results of the sleep heart health study. Am J Respir Crit Care Med 2001;163:19–25.
[7] Bacon WH, Krieger J, Turlot J-C, et al. Craniofacial characteristics in patients with obstructive sleep apnea syndrome. Cleft Palate J 1988;25: 374–8.
[8] Rivlin J, Hofstein V, Kalbfleisch J, et al. Upper airway morphology in patients with idiopathic obstructive sleep apnea. Am Rev Respir Dis 1984; 129:355–60.
[9] Riley R, Guilleminault C, Herran J, et al. Cephalometric analyses and flow-volume loops in obstructive sleep apnea patients. Sleep 1983;6: 303–11.
[10] Riley R, Guilleminault C, Powell N, et al. Palatopharyngoplasty failure, cephalometric roentgenograms, and obstructive sleep apnea. Otolaryngol Head Neck Surg 1985;93:240–4.
[11] Kribbs NB, Pack AI, Kline LR, et al. Objective measurements of patterns of nasal CPAP use by patients with obstructive sleep apnea. Am Rev Respir Dis 1993;147:887–95.
[12] Katsantonis GP, Schweitzer PK, Branham GH, et al. Management of obstructive sleep apnea: comparison of various treatment modalities. Laryngoscope 1988;98:304–9.
[13] Waite PD, Wooten V, Lachner J, et al. Maxillomandibular advancement surgery in 23 patients with obstructive sleep apnea syndrome. J Oral Maxillofac Surg 1989;47:1256–61.
[14] Riley RW, Powell NB, Guilleminault C. Obstructive sleep apnea syndrome: a review of 306 consecutively treated surgical patients. Otolaryngol Head Neck Surg 1993;108:117–25.
[15] Powell NB, Riley RW, Guilleminault C, et al. Obstructive sleep apnea, continous positive airway pressure, and surgery. Otolaryngol Head Neck Surg 1988;99:362–9.
[16] Riley RW, Powell NB, Guilleminault C, et al. Obstructive sleep apnea surgery: risk management and complications. Otolaryngol Head Neck Surg 1997;117(6):648–52.