According to the CDC, in 2009, “An estimated 50–70 million adults in the United States have chronic sleep and wakefulness disorders. Sleep difficulties, some of which are preventable, are associated with chronic diseases, mental disorders, health-risk behaviors, limitations of daily functioning, injury, and mortality. The National Sleep Foundation suggests that most adults need 7–9 hours of sleep per night, although individual variations exist. To assess the prevalence and distribution of selected sleep difficulties and behaviors, CDC analyzed data from a new sleep module added to the Behavioral Risk Factor Surveillance System (BRFSS) in 2009. This report summarizes the results of that analysis, which determined that, among 74,571 adult respondents in 12 states, 35.3% reported having <7 hours of sleep on average during a 24-hour period, 48.0% reported snoring, 37.9% reported unintentionally falling asleep during the day at least 1 day in the preceding 30 days, and 4.7% reported nodding off or falling asleep while driving in the preceding 30 days.”

“For the purposes of the following discussion, it is useful to define the breathing events being examined. These breathing events include the following:

- Apnea
- Hypopnea
- Respiratory effort–related arousal (RERA)

Apnea is defined by the American Academy of Sleep Medicine (AASM) as the cessation of airflow for at least 10 seconds. Apnea may last for 30 seconds or even longer.

Hypopnea is defined as a recognizable transient reduction (but not complete cessation) of breathing for 10 seconds or longer, a decrease of greater than 50% in the amplitude of a validated measure of breathing, or a reduction in amplitude of less than 50% associated with oxygen desaturation of 4% or more. An arousal is unnecessary to score a hypopnea.
An RERA is an event characterized by increasing respiratory effort for 10 seconds or longer leading to an arousal from sleep but one that does not fulfill the criteria for a hypopnea or apnea. The criterion standard to measure RERAs is esophageal manometry, as the AASM recommends. However, esophageal manometry is uncomfortable for patients and impractical to use in most sleep centers." 3

Sleep apnea severity is graded based on the AHI: the number of apneas, plus the number of hypopneas measured while the patient is asleep, divided by the time spent asleep to give an average number per hour of respiratory events. An AHI of less than 5 events per hour is considered normal in adults. Mild sleep apnea is an AHI of 5-15, Moderate is AHI of 15-30, Severe is AHI greater than 30 events per hour, or an average of one hypopnea or apnea every 2 minutes or less.

Treatment options include behavioral modification, devices that can be worn, or surgical options. Some patients with mild sleep apnea need only to sleep on their sides. Alcohol avoidance and weight loss can also help some mild cases resolve. There are a variety of oral devices that can be worn to advance the jaw or tongue during sleep. CPAP or BiPAP facial mask or nasal devices are the gold standard for treatment of sleep apnea at this time.

For preoperative evaluation of the sleep apnea patient, a good Sleep History should be taken. The Physical exam should include a thorough head and neck exam including Friedman scores for palate and tonsils, Neck circumference, BMI, and the Muller Maneuver. Imaging may include Xray, CT, MRI for cephalometrics. Polysomnography is necessary to make the diagnosis of sleep apnea and assign a severity. Identifying the site of obstruction on physical exam is challenging. “Numerous other methods have been used to predict the location of the upper airway obstruction—including physical examination, computed tomography, magnetic resonance imaging, and fluoroscopy. As with cephalometric studies, these studies all are valuable in research studies but have not been shown to be of clinical value. The most commonly used test is the Muller maneuver (MM). Borowiecki and Sassin first described this maneuver for the preoperative assessment of SDB. The MM consists of having the patient perform a forced inspiratory effort against an obstructed airway with fiberoptic endoscopic visualization of the upper airway. The test is widely used and simple to perform. Despite this, its use is controversial and certainly no studies have been able to associate the maneuver as a tool to select patients who are likely to succeed with UPPP.” 7

Friedman has developed a staging system to predict success rates of uvulopalatopharyngoplasty (UPPP) in achieving cure of sleep apnea predicted with grading systems based on physical exam and BMI for mouth opening and tonsillar size. The Friedman tongue position (FTP) describes several grades of mouth opening. “FTP I allows visualization of the entire uvula and tonsils/pillars. FTP IIa allows visualization of most of the uvula, but the tonsils/pillars are absent. FTP IIb allows visualization of the entire soft palate to the base of the uvula. In FTP III some of the soft palate is visualized but the distal structures are absent. FTP
IV allows visualization of the hard palate only." The tonsil grading scale is similar: “Tonsils, size 0, s/p tonsillectomy. Tonsils, size 1, within the pillars. Tonsils, size 2, extend to the pillars. Tonsils, size 3, extend past the pillars. Tonsils, size 4, extend to the midline.” Combining these grades stages the patient for probability for cure. Lower stages predict higher success rate of UPPP alone to treat OSA

<table>
<thead>
<tr>
<th>Stage</th>
<th>FTP</th>
<th>Tonsil size</th>
<th>BMI</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>I, IIa, IIb</td>
<td>3 or 4</td>
<td>&lt;40</td>
</tr>
<tr>
<td>II</td>
<td>I, IIa, IIb</td>
<td>0, 1, or 2</td>
<td>&lt;40</td>
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<tr>
<td></td>
<td>III or IV</td>
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<td>III</td>
<td>III or IV</td>
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The Friedman algorithm for treatment is as follows: Mild (AHI 5-15) sleep apnea can be treated in two ways. For symptomless patients, behavior modification is often all that is needed. For patients exhibiting symptoms like daytime sleepiness and inability to concentrate, behavior modification, adding a worn device like a mouthpiece or CPAP, or you may consider surgery. For moderate sleep apnea, (AHI 15-30) with no symptoms, consider behavior changes or adding a device. For patients with symptoms, a device, usually CPAP should be trialed, and consider surgery for device failures. For severe (AHI >30) OSA patients, devices are first line therapy, consider surgery as adjunct to help with tolerance of CPAP (help to achieve cure at a lower setting), refer for bariatric surgery for patients with BMI>40. As usually a last resort, consider tracheostomy.

Another way of approaching this issue is to consider the indications for surgery. Apnea/Hypopnea Index (AHI) >20, Oxygen desaturation nadir <90% during the sleep study, esophageal pressure (PES) more negative than –10 cm H2O during polysomnography, Cardiovascular derangements (arrhythmia, hypertension), neurobehavioral symptoms (excessive daytime sleepiness), failure of medical management, and clear anatomical sites of obstruction (nose, palate, tongue base) are all indications for surgical management.

Powell and Riley have outlined a protocol for phasing sleep apnea procedures. In their phase I, the following procedures may be considered alone or in combination to alleviate anatomical obstructions. Nasal surgery (septoplasty, turbinate reduction, nasal valve grafting), Tonsillectomy, Uvulopalatopharyngoplasty (UPPP) or uvulopalatal flap (UPF), Mandibular osteotomy with genioglossus advancement, Hyoid myotomy and suspension, Temperature-controlled radiofrequency (TCRF) of turbinates, palate, or tongue base. Their phase II should
only be considered if phase I procedures are tried and are unsuccessful and involves Maxillomandibular advancement osteotomy (MMO) and/or Temperature-controlled radiofrequency (TCRF) of the tongue base. This discussion will focus mainly on phase I procedures.

**Nasal Surgeries**

Nasal surgery is well described to alleviate nasal obstruction even without sleep apnea, including septoplasty and inferior turbinate reduction. Alar batten grafts or spreader grafts may be placed during rhinoplasty to relieve internal valve collapse. Tonsillectomy and adenoidectomy are indicated especially in children with OSA to relieve posterior nasal and oropharyngeal obstruction.  

**Palatal Surgeries**

Many palatal surgeries may be considered for relieving obstruction involving the upper oropharynx. Snare Uvulectomy is simple removal of the uvula for upper airway resistance syndrome and simple snoring, but has no studies comparing AHI pre and post procedure. Cautery assisted palatal stiffening may be considered for upper airway resistance syndrome, simple snoring, or mild OSA. One study shows AHI improvement from 12.3 to 5.2 with this method. Injection snoreplasty is indicated for simple snoring caused by palatal flutter. In one study, 76.7 to 92% of patients experienced improved snoring. One downside to this procedure is that it does not last long term; however, it may be repeated if the first time is successful.

Palatal Implants (Pillar®) may be considered. These are minimally invasive and less painful than other palatal surgeries and consist of woven cylindrical implants inserted to stiffen palate and reduce palatal flutter causing snoring. They are indicated for simple snoring and therefore are not usually covered by insurance as snoring procedures are considered cosmetic. Patients that benefit from this have small tonsils more than 2 cm apart, no signs of tongue base collapse, FTP I or II, and redundant palatal tissue. Implantation can be performed under local anesthesia in the office. Extrusion rate per patient is about 10%. The Pillar reduces snoring sound intensity, but does not completely eliminate snoring. A recent 4 year longitudinal study showed that subjective improvement degrades over time to nearly baseline.

UPPP is resection of part of the anterior tonsillar pillars, the bilateral tonsils, and the uvula in an arched curve. The pillars are then approximated with suture to promote wound healing and scarring. Success is defined as reduction in AHI by 50% to less than 20 events per hour. For Friedman stages, success rates are Stage I, 81% Stage II, 37% Stage III, 8%.

Fairbanks technique, which involves a more aggressive lateral and superior palatal resection in more of a rectangular resection is reported to improve on traditional UPPP by improving lateralization of pillars. This technique minimizes shortening of the soft palate to maintain velopalatine valvular patency. Reported results are similar to traditional UPPP.
Zetapalatopharyngoplasty is a technique indicated for patients with prior history of tonsillectomy with OSA. It is indicated for Friedman Stage II and III patients with moderate to severe OSA. The uvula is transected medially and lateral palatal flaps are demucosalized. The flaps created by the transected uvula are rotated up to cover the demucosalized palate. The healing process creates tension lateral and cranially instead of the tension of UPPP healing which can be medial and caudally. ZPPP therefore is theorized to widen the retropalatal space. This technique does carry a greater risk for VPI, but cure rates for stage II patients who also undergo tongue base RF with ZPPP is reported as 70%.  

A uvulopalatal flap has been performed where the anterior surface of the medial soft palate and uvula are demucosalized and the uvula is rotated up to the palate and sutured. This procedure can be performed under local anesthesia and is initially reversible if desired outcome is not achieved.  

Palatal advancement pharyngoplasty shortens the bony palate with osteotomy to increase the nasopharyngeal opening. This technique has the advantage of maintaining the structural attachments of the soft palate constrictors to the posterior edge of the hard palate while shortening the overall hard palate length. Studies of this technique report a decreased RDI from average of 52.8 to 12.3 in responder group, and success rates improved over UPPP alone for Stage III patients. 

**Tongue Base Surgeries**

Tongue base reduction uses radiofrequency electrodes to create scar tissue contraction and therefore volume reduction in the base of the tongue. It can be an in-office procedure done under local with minimal side effects, and may be repeated to optimal effect. It is more effective when used in conjunction with UPPP. 

Submucosal Lingualplasty utilizes an open approach to address macroglossia. An incision is made in the posterior midline of the tongue and excess muscle is removed medially and superiorly while avoiding the neurovascular bundles laterally. The reduction in tongue volume increases airway volume. Bleeding into the surgical cavity postoperatively is the most dangerous complication as the airway may be acutely compromised with even a minor bleed. The proponents of this method recommend meticulous hemostasis with clips prior to closure. 

A percutaneous variation on this technique called SMILE (Intraoral submucosal minimally invasive lingual excision) has been reported to have good success in Down’s syndrome children. Initially, neurovascular bundles are identified with ultrasound. Then the tongue base is approached percutaneously with coblation followed by copious irrigation through endoscope until sufficient volume is removed. 

The tongue base may be suspended to the mandible for anterior traction during sleep. The Repose system provides a minimally invasive approach to this procedure. A screw is
implanted into the mandible above the genial tubercle and nonabsorbable sutures are drawn through the tongue base and tightened to create a sling which holds the tongue base anteriorly. This is not indicated for OSA caused by retropalatal upper airway obstruction. Relative contraindications include macroglossia and poor oral hygiene. Success rates are reported as 51-78%, some in combination with UPPP or other palatal techniques.  

Lingual tonsillectomy may be performed if lingual tonsil hypertrophy is considered to be contributing to hypopharyngeal collapse. Definition of this condition is subject to some debate as the lingual tonsils do not have clear anatomical boundaries or sizing criteria. One study proposes lingual tonsillectomy is indicated if they are 10 mm in diameter and abutting both the posterior border of the tongue and the posterior pharyngeal wall.  

**Multilevel pharyngeal surgeries**

Hyoid myotomy and suspension is a variation on the Repose tongue base suspension technique where the anchoring screw above the genial tubercle retains suspension sutures that pass around the middle portion of the hyoid bone and are tightened to create anterior traction on the hypopharyngeal walls. One study shows improvement in AHI from an average of 40 to an average of 19.  

Genioglossus advancement with mandibular osteotomy uses an intraoral approach to the anterior mandible to create an osteotomy that is pulled forward and secured to the remaining mandible. This technique creates traction on the tongue base by advancing the genioglossus muscle with the osteotomy. Shapes can vary but rectangular osteotomies tend to be less invasive and better preserve mandibular integrity. The success rate of this method is variable from 22-67%.  

**Other surgeries**

Maxillomandibular advancement osteotomy with rigid fixation is a Phase II procedure. It involves mandibular osteotomies and plate placement to advance the mandible plus advancement of the maxilla via a surgical Lefort osteotomy resulting in advancement of the entire oral cavity. Documented success rates of >90% make this complicated procedure valuable as a secondary consideration if other techniques have failed.  

The only 100% successful procedure to correct OSA is tracheostomy. The lifestyle changes required by this procedure make it less attractive to patients than others, but some techniques are practiced to create hands-free stomas using strap muscles that reduce the usual burdens of tracheostomy dependence.  

Bariatric surgery has been utilized to reduce BMI, which reduces AHI. A recent meta-analysis of bariatric surgery effect on AHI found that with an average BMI change from 55 to 37
after surgery, average AHI was reduced from 55 to 16. Bariatric surgery therefore meets criteria for a successful OSA intervention and should be kept in mind for the appropriate patients. 11

In conclusion, sleep disorders are multifactorial and often multilevel. Milder cases respond more readily to single intervention or lifestyle changes. In general, the more severe the sleep disorder, the more involved the intervention. It is important to note that surgical cure usually only provides reduction in severity and CPAP will likely still necessary, but can be more tolerable to patients with sleep apnea.

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