Chapter 77: Sleep Apnea Disorders

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Manifestations of sleep apnea have been present in our society for many years. Snoring, restless sleep, and daytime drowsiness have been well recognized by the lay public, but until recently the understanding, evaluation, and treatment of these symptoms have largely eluded physicians. During the past 10 to 15 years, information concerning sleep apnea has increased rapidly. Sleep studies have demonstrated the significant cardiopulmonary problems that may be associated with obstructive sleep apnea.

Sleep apnea may present as a broad spectrum of symptoms that can range from snoring to life-threatening cardiac and pulmonary complications. Otolaryngologists-head and neck surgeons are increasingly being asked to evaluate symptoms that may be related to sleep apnea. The lay public is becoming more educated concerning the significance of snoring, restless sleep, and daytime drowsiness. With the availability of more information, it has become obvious that sleep apnea has great significance to a wide range of cardiopulmonary and other medical problems.

Apnea is defined as the cessation of airflow at the nostrils and mouth for at least 10 seconds. Three general types have been described. *Obstructive apnea* is a cessation of airflow in the presence of continued inspiratory effort. *Central apnea* is the absence of both airflow and inspiratory effort. *Mixed apnea* is a combination of both components, beginning as central apnea followed by the onset of inspiratory effort without airflow (Fig. 77-1) (Bornstein, 1982).

Sleep Physiology

Polygraphic recordings during sleep, consisting of an electroencephalogram (EEG), electrooculogram (EOG), and chin electromyogram (EMG), have shown sleep to be a complex state. During various stages of sleep, the EEG may show patterns of activity compatible with cortical sedation as well as intervals compatible with cortical activation. The activation pattern is encountered during rapid eye movement (REM) sleep, the stage of sleep characterized by a burst of rapid conjugate eye movements and substantially decreased REM activity that is most commonly associated with dreaming. In contrast, nonrapid eye movement (NREM) sleep is divided into stages 1 to 4 according to the types of EEG waveforms. The temporal pattern of REM and NREM sleep is a cycle with a periodicity of approximately 90 minutes. Most normal people experience three to five periods of REM sleep in an average night.

The physiology of REM and NREM sleep varies considerably; during NREM sleep the autonomic nervous system is relatively quiescent and the respiratory rate, heart rate, and blood pressure reach their lowest levels. These physiologic measurements are well regulated and show relatively little variability during this stage. In contrast, REM sleep is a time of increased autonomic activation, manifested by periodic evaluations in the heart rate, respiration rate, and blood pressure. A substantial degree of variability is encountered in these measurements during REM sleep (Baker, 1985).

During REM sleep associated with intercostal muscle inhibition, thoracic respiration may decrease, leading to a degree of mechanical instability that, under certain clinical circumstances, may produce decreased lung volume and greater susceptibility to hypoxemia. Decreased muscular activity during REM sleep has been demonstrated in some of the upper respiratory tract muscles, creating an increased susceptibility to airway occlusion during sleep (Krol et al, 1984; Tusiewicz et al, 1977). Decrease in the activity of the genioglossus and medial pterygoid muscles may allow for significant jaw retrusion during sleep, making the airway considerably more susceptible to occlusion via a prolapse of the tongue (Sauerland et al, 1981).

Normal airway patency is maintained as a result of the dilating action of the respiratory muscles of the upper airway. Airway occlusion may ensue if this dilating force is overcome by a sufficient negative intrathoracic pressure; thus the normal function of the upper airway depends on the normal phasic inspiratory activity of the several muscles in this area.

Measurements of ventilation during normal sleep show various changes and responsiveness to the carbon dioxide and oxygen drives. During NREM sleep there is a depressed carbon dioxide responsiveness, and the hypoxic drive also appears to be diminished during both NREM sleep and REM sleep in humans. In addition, the threshold for arousal from REM sleep to the hypoxic stimulus appears to be substantially elevated.

Pathophysiology of Sleep Apnea

The correct evaluation of sleep disorders requires careful monitoring of airflow at the nose and mouth, as well as monitoring of thoracic breathing movements. These measurements also are combined with standard monitoring of the electrocardiogram (ECG) and ear oximetry. Basic data from an overnight sleep study include the type and frequency of apneic episodes, the relationship of these apneic episodes to cardiac arrhythmias and oxygen desaturation, and the incidence of the apneic episodes during REM and NREM sleep. The *apnea index* is the number of apneic episodes per hour of sleep. Although an apnea index greater than 5, with apneic episodes occurring during both REM and NREM sleep, has been considered diagnostic for sleep apnea, clinically symptomatic patients usually have an apnea index greater than 30. In general, periods of apnea last 20 to 30 seconds, seldom exceed 100 seconds, and are longer during REM sleep than during NREM sleep.

Three variables are important in the development of the collapse and obstruction of the upper airway: the decreased activity of the muscle dilators of the pharyngeal airway, the relative vacuum generated in the upper airway during inspiration, and the surgical anatomy of the upper airway (Remmers et al, 1978). In patients who have obstructive apnea, the site of the predominant airway obstruction has been localized to the supralaryngeal portion of the airway. This has been demonstrated by simultaneos recording of the pressure in both the esophagus and the supraglottic airway, as well as by fluoroscopic and direct fiberoptic observation (Borowiecki et al, 1978; Suratt et al, 1983).

The occlusion typically begins in the oropharynx with the tongue contacting the soft palate and posterior pharyngeal wall (Fig. 77-2), followed by progressive collapse of the lower pharyngeal airway. In addition to obstruction in the anteroposterior direction, progressive collapse of the lateral oropharyngeal wall also has been demonstrated. Periods of obstructive apnea usually are terminated by brief arousals that increase pharyngeal muscular activity sufficiently to maintain airway patency (Thawley and Shepard, 1985).

Apnea duration is largely determined by the briskness of the arousal response to the stimuli in REM sleep as compared with NREM sleep, apneic episodes usually last longer during REM sleep (Tikian et al, 1977).

Disorders producing anatomic narrowing of the upper airway and thereby necessitating the generation of more negative inspiratory pressures to maintain ventilation of obstructive apnea. Significant structural narrowing of either the oral or hypopharyngeal airway, or both, has been confirmed by computed tomography (CT) in many patients with obstructive sleep apnea (Burstone et al, 1978). These findings often correlate with the clinical finding of large tonsils, excessive tissue in soft palate, a large uvula, and a large base of tongue area (Fig. 77-3). In many patients excessive tissue in the pharynx with multiple folds of pharyngeal mucosa also is clinically noted.

During apneic events, corresponding arterial carbon dioxide pressure ($PaCO_2$) increases and corresponding arterial oxygen pressure (PaO_2) decreases (Fig. 77-4). Apneic episodes of 60 seconds will generally decrease the PaO_2 concentration by as much as 35 to 50 mmHg. Since lung volume and alveolar PaO_2 are the major determinants of lung oxygen stores, factors that reduce lung volume (the supine position and obesity) an PaO_2 (hyperventilation) acto together to reduce lung oxygen stores and accelerate the rate of oxygen desaturation. These factors contribute to the severity of oxygen desaturation observed in obstructive sleep apnea patients who are obese and who hypoventilate (Shepard, 1984).

Pulmonary and systemic arterial pressures increase in response to nocturnal oxygen desaturation irrespective of the type of apnea. These elevations in pressure may be substantial an can contribute to ventricular hypertrophy and eventual decompensation. Systemic hypoxemia stimulates catecholamine release, elevated levels of which have been reported in patients with sleep apnea. This may contribute to the development of systemic hypertension in these patients (Clark et al, 1980).

Apneas commonly are associated with prominent sinus arrhythmia. The extent of cardiac slowing increases in proportion to the severity of the oxygen desaturation. Cardiac slowing occurs to the greatest degree in obstructive apneas that involve the performance of a Mueller maneuver. The bradycardia is mediated by increased vagal efferent activity. Long-term physiologic consequences of apneic events clearly depend on frequency an duration, as well as the severity of the hypoxemia and associated hypertensive responses. In individual patients these variables are modified by coexisting cardiopulmonary disorders.

In patients with obstructive sleep apnea, alveolar ventilation during an apneic episode is reduced to zero, and the metabolic demands for oxygen must be met from oxygen stores within the body. As the stores of oxygen within the lung are diminished, the rate of arterial oxyhemoglobin desaturation increases. Coexistent cardiopulmonary or neuromuscular disease in patients with obstructive sleep apnea contributes to the development of alveolar hypoventilation. During apneic episodes, the systemic bloo pressure increases while the heart rate and cardiac output decrease. Both bradycardias and increased ventricular ectopic activity have been associated with these disordered breathing episodes. Because of the possibility of apnea-associated arrhythmias, patients with obstructive sleep apnea may be at increased risk for cardiovascular mortality (Shepard, 1990).

The mortality of obstructive sleep has been unclear. Although the resultant oxygen saturation and arrhythmias would seem likely to increase the rsik of death, until recently few stuies have shown a definite increased mortality. In one study patients with an apnea index greater than 20 had a much greater mortality than those with an index of less than 20. The cumulative survival of the group treated with only uvulopalatopharyngoplasty was not different from the survival curve of untreated obstructive apnea patients with an apnea index greater than 20. The difference in mortality was particularly true in the patients less than 50 years of age in whom mortality from other causes is not common (He et al, 1988).

The obstructive apnea event is characterized by collapse of the pharyngeal airway at the level of the oropharynx and hypopharynx. There has been some question as to whether this collapse is passive or active. The patency of the pharyngeal airway is under partial control of the central nervous system, and involuntary adjustments in muscle tone are responsible for maintaining an adequate airway. The pharyngeal muscles must increase their tone to resist the tendency of the walls of the pharynx to collapse in the inspiratory airstream. Factors that may contribute to the collapse of the pharyngeal airway include atmospheric pressure, weight of cervical tissue, compliance of the airway walls, and inspiratory negative pressure within the airway (Fig. 77-5).

Compliance of the walls of the pharyngeal airway is quite variable, depending on local factors and, most important, the tone of the musculature of the pharynx. Negative pressure within the lumen of the airway is essentially controlled by the resistance to airflow and the opening pressure within the alveoli. Any lesion increasing resistance to airflow, whether in the upper or lower airway, would necessarily increase the amount of effort required to maintain airflow. This in turn increases negative intraluminal pressures and the tendency of the airway to collapse. The small size of the oropharynx in sleep apnea patients has been demonstrated by CT scans (Fig. 77-6) (Haponik, 1983). Correlations of direct fiberoptic videoscopic evaluation and polysomnographic sleep recordings have demonstrated that during obstructive sleep apnea events, the glottis remains widely patent at all times. Collapse of the airway seems to be passive and primarily related to the high intraluminal negative pressures associated with hypotonic pharyngeal walls and disproportionate anatomy in the oropharynx, the hypopharynx, or both. The disproportionate anatomy consists of any combination of a large base of tongue, large soft palate, shallow palatal arch, narrow mandibular arch, or retrognathic mandible. The collapse of the pharyngeal airway appears to be a passive event, since it can be stopped when the predisposing condition or disproportionate anatomy is bypassed by tracheotomy.

Certain drugs may contribute to the severity of obstructive sleep apnea. These include alcohol (Taasan et al, 1981), sedatives, tranquilizers, sleeping pills, antiepilepsy drugs, and antihistamines. These commonly suppress the hypoxemia, hypercapnia, and respiratory drive reflexes and may indeed be dangerous in patients with obstructive sleep apnea.

Associated Disorders

Central sleep apnea is uncommon and is usually a sequelae of traumatic, infectious, ischemic, or neoplastic injury to the brain stem where the respiratory control centers are located. Because of the close relationship between thyroid hormone and tissue metabolic activity and ventilation, recent reports of central and obstructive sleep apnea in relationship to hypothyroidism are not surprising (Orr et al, 1981; Skatrud et al, 1981).

Obesity is the major disorder associated with obstructive sleep apnea, and a considerable overlap exists of patients with obstructive sleep apnea and patients with obesity-hypoventilation syndrome (Lopata, 1982). Obese patients with obstructive apnea have been observed to develop carbon dioxide retention with added respiratory loads secondary to additional weight gain, respiratory infections, or congestive heart failure. In addition to thyroid hormones, sex hormones are believed to play an important role in the development of obstructive sleep apnea. Not only does obstructive apnea occur predominantly in men, but also high levels of testosterone have been associated with development of the syndrome (Block et al, 1979). In contrast, progesterone, which is known to stimulate ventilation, may contribute to the low frequency of disordered breathing during sleep in premenstrual women (Block et al, 1980).

Clinical disorders associated with structural narrowing of the upper airway (adenotonsillar hypertrophy, pharyngeal neoplasms, macroglossia, and micrognathia) clearly predispose a person to the development of obstructive apnea. In these patients findings suggest that upper airway obstruction is likely to occur during sleep. Patients with epistaxis treated with both anterior and posterior nasal packs may have significant obstructive sleep apnea with decreased oxygen saturation. This may contribute to the sudden deaths that have been reported in epistaxis patients with nasal packing. When the packs are removed the obstructive apnea and oxygen saturation are improved (Wetmore et al, 1988). Obstructive sleep apnea has been reported in patients after irradiation of the neck. This may be secondary to supraglottic edema and aggravated by hypothyroidism, which may cause both obstructive and central apnea (Herlihy et al, 1989).

Diagnosis

History

Many patients and spouses will have correctly diagnosed sleep apnea by noting the history of excessive snoring, restless sleep patterns, or apneic events at night, as well as daytime drowsiness. In most cases the spouse gives a more accurate description of the symptoms than the patient.

Bed partners of obstructive sleep apnea patients commonly describe very lou, disruptive snoring; when the obstructive event occurs, the snoring sound stops with a cessation of airflow and the careful observer may note that the patient continues respiratory efforts but that there is no airflow through the mouth or nasal area. The apneic periods last generally 10 to 60 seconds and sometimes as long as 2 minutes. At the end of the obstructive component, an arousal occurs secondary to the stimulants of hypoxemia and hypercapnea (see Fig. 77-5). This is followed by a strained snore that frequently is accompanied by myoclonic jerks, and the snoring then resumes, followed by another obstructive apneic event.

The snoring sound results from the passage of air through the oropharynx, producing vibrations of the soft palate. The relaxed tone of the muscles in this area is believed to contribute to the excessive vibrations associated with the snoring noise. Increased negativity in the inspired air secondary to the obstruction may increase the turbulence in the area, thus aggravating the snoring noise.

The symptom of excessive daytime sleepiness, or hypersomnolence, is thought to be related to the frequency of nocturnal arousals resulting in fragmentation of sleep, although some investigators believe that the severity of nocturnal hypoxemia also is an important contributing factor. Daytime hypersomnolence clearly impairs cognitive function as well as motor task performance. It is not unusual that patients or spouses describe intellectual deterioration, increasing inattentiveness, and difficulty in concentrating. Many experience personality change, as well as morning headaches. Although present in many patients, hypersomnolence is not present in all patients with an ostensible significant degree of obstructive sleep apnea (Moran et al, 1984). Symptoms rarely volunteered, but frequently elicited from a careful history, are intermittent nocturnal enuresis (Weider et al, 1991) and impotence. Patients with this affliction commonly fall asleep while talking with someone or when sitting for a few minutes (Fig. 77-7). In addition, falling asleep while driving a vehicle is not uncommon, and interference with social and professional life frequency occurs. Everyone who snores does not necessarily have obstructive sleep apnea. However, virtually all patients with obstructive sleep apnea have significant snoring problems.

Finally, the history may indicate nasal, facial, or pharyngeal trauma that may, in retrospect, have triggered the later onset of snoring or obstructive sleep apnea. This may have produced nasal septal deviation with complete or partial obstruction of the nasal cavity. Lesions in the pharynx may produce dysphagia or a "lump in the throat" sensation. Patients should be questioned specifically regarding appearances or changes in neck masses, especially in the thyroid area. A history of recent weight gain and symptoms related to myotonic dystrophy should be specifically sought.

Physical findings

Approximately 70% of patients with obstructive sleep apnea are 15% heavier than their ideal body weights, an a significant number have short, thick necks (Fig. 77-8) with excessive cervical tissue (Guilleminault et al, 1978).

Systemic hypertension has been reported in 30% to 50% of cases (Tilkian et al, 1976). Clinically evident pulmonary hypertension selom is present unless the patients have either concomitant chronic lung disease or alveolar hypotentilation (Boysen et al, 1979). Cardiomegaly with right and left ventricular failure occurs in patients with severe obstructive sleep apnea, but obesity, hypertension, or underlying heart disease frequently coexists as a predisposing cause. In addition, detection of polycythemia usually, but not always, implies daytime as well as nocturnal hypoxemia.

The examination should include the mouth, nasal, pharyngeal, laryngeal, and neck areas. The pharynx and larynx should be examined indirectly with a laryngeal mirror, and direct fiberoptic examination through the nose should be performed in both the sitting an reclining positions. The physician may note obstruction secondary to a deviated nasal septum. Occasionally there may be a mass in the nasopharynx such as a cyst, tumor, or antral choanal polyp (Rodgers et al, 1991). Obstructions in the hypopharynx include cysts of the base of the tongue, vallecula, and epiglottis (Fig. 77-9). Tumors in the hypopharynx may also be noted. In most patients with typical classic obstructive sleep apnea, a specific obstructive lesion is not noted. Frequently these patients have an excessive amount of tissue in the oropharynx, characterized by a low-hanging redundant palate (Fig. 77-10), large tonsils, and excessive pharyngeal mucosal folds. Examination of the oropharynx frequently reveals enlargement of the uvula, prominent oropharyngeal folds, and a small oropharyngeal orifice. Commonly the base of the tongue is large in these patients, and frequently the tongue simply appears too large for the mouth.

A minority of patients with significant obstructive sleep apnea are thin and have no apparent anatomic abnormalities on physical examination, and their oropharyngeal inlet appears widely patent.

Diagnostic testing

Polysomnogram

A nocturnal polysomnogram confirms the diagnosis of sleep apnea and defines its severity. This study is performed overnight in a sleep laboratory, and the patient's sleep is monitored. The minimum diagnostic evaluation of the sleep study should include determination of the stages of sleep, identification of the types of apneic events, continuous monitoring of arterial oxygen saturation, and documentation of cardiac arrhythmias in relationship to the apneic events and oxygen desaturation (see Fig. 77-4) (Orr, 1985). Polysomnography is helpful in allowing physicians to decide on a correct course of management. It is also quite helpful to patients in order to educate them regarding the magnitude and potential seriousness of the problem. Some patients simply do not understand the potential seriousness of the problem until it can be demonstrated to them on a sleep study that they are intermittently apneic and that their oxygen saturation is decreasing during these periods.

Multiple sleep latency test

The multiple sleep latency test (MSLT) provides and objective assessment of the tendency to sleep. It correlates well with the subjective feelings of excessive daytime sleepiness. It basically measures the amount of time required for a patient to fall asleep. The mean sleep onset latency in normal persons is 10 to 15 minutes. Patients with obstructive sleep apnea, who have excessive daytime sleepiness, commonly have a much reduced sleep onset time (Orr, 1985).

Other diagnostic methods

Inspiratory and expiratory flow volume loops determine if a sawtooth pattern is present, or if the ratio of expiratory to inspiratory flow, at 50% of vital capacity, exceeds 1 in the absence of obstructive airway disease (Sanders et al, 1981). Videoendoscopic examination during obstructive sleep periods may provide objective dynamic evidence of mechanical structural narrowing of the upper airway (Rojewski et al, 1984). Arterial blood gas analysis yields important information concerning the adequacy of alveolar ventilation, severity of hypoxemia, and acid-base status during wakefulness. A blood count is useful to determine the presence of polycythemia. Other blood studies evaluate thyroid function. Patients identified in the sleep study as having predominantly central sleep apnea should be carefully evaluated for lesions involving the brain stem. CT evaluation of the upper airway has been used in patients with predominantly obstructive sleep apnea to determine both the level and severity of the anatomic narrowing (see Fig. 77-6). Recently cine CT scans with multiple-level rapid-sequence scans have been used to determine the site of airway obstruction (Eli et al, 1986). This may represent an improved method to study with pathophysiology of the upper airway in this syndrome. Three-dimensional CT reconstructions of the upper airway, tongue, and soft palate volume may provide information concerning the areas of most likely obstruction (Lowe et al, 1986). Fluoroscopy may also be helpful to confirm the area of obstruction (Walsh and Katsantonis, 1984). Cephalometry may be useful in determining the anatomic relationships of the soft palate, pharynx, tongue, hyoid, and mandible and may be used to help decide which surgical procedure may be indicated and successful (Ryan et al, 1990). Rhinomanometry may measure the amount of nasal resistance, and acoustic rhinometry may determine the size an location of the different stenoses in the nasal cavity that contribute to the increased nasal resistance (Lenders et al, 1991).

Differential diagnosis

The differential diagnosis of obstructive sleep apnea in adults is usually not difficult when the classic history and typical physical findings are present. Because of the daytime hypersomnolence in obstructive sleep apnea, this condition may be confused with narcolepsy.

Narcolepsy is a sleep disorder characterized by episodes of sudden onset of short duration. These may occur at any time, usually lasts about 15 minutes, and occur 1 to several hours apart. The onset of this disease usually takes place between the ages of 10 to 20 years. Both sexes are equally affecte. Narcolepsy may be associated with episodes of cataplexy, a sudden loss of tone in the major striated muscles that occurs at the onset of sleep, and hypnogogic hallucinations (auditory, visual, or tactile hallucinations that occur at the onset of sleep) are also seen in association with narcolepsy. Nocturnal sleep problems frequently coexist. The diagnosis is confirmed by the presence of REM-onset sleep during a daytime sleep study (Baker, 1985).

Heart disease, congestive heart failure, chronic obstructive lung disease, and pulmonary fibrosis may have some of the symptoms as obstructive sleep apnea, but usually these conditions can be diagnosed with a good history and physical examination combined with pulmonary function and cardiac function tests. These conditions may coexist with obstructive sleep apnea an contribute to the symptoms and physical findings. Obesity may produce alveolar hypoventilation, hypercapnia, hypoxemia, right-sided heart failure, and daytime hypersomnolence (pickwickian syndrome). The excessive tissue in the oropharynx may predispose to collapse of the oropharynx during sleep so that obstructive sleep apnea may be a factor.

Medical Management

The therapeutic approach depends on the predominant type of apnea to be treated, as well as the severity of the resulting functional and physiologic disabilities. Patients who do not have sleep apnea yet have significant snoring problems may be candidates for an uvulopalatopharyngoplasty (UPP) procedure to decrease snoring. This enlarges the airway and decreases the palatal vibrations.

Irrespective of the predominant type of apnea, all patients should be advised to avoid the use of drugs that depress the central nervous system, such as alcohol, which has been shown to increase the frequency of disordered breathing and the severity of oxygen desaturation in normal persons, as well as in patients with sleep apnea.

Weight loss should be encouraged in all obese apnea patients to decrease the mass load placed on the respiratory system, to increase the resting lung volume, and to improve gas exchange (Elmirgil and Sobol, 1973; Harman and Block, 1986; Vaughan et al, 1981. Although weight reduction can decrease the severity of apnea and desaturations in obese persons, the clinical response is variable (Harman et al, 1982). In practical terms, weight loss by dietary measures alone is seldom maintained on a long-term basis.

Medications that decrease the amount of time a patient is in REM sleep are considere helpful, since sleep apnea is worse during REM sleep with its associated muscle relaxation. *Progesterone,* a recognized respiratory stimulant, increases alveolar ventilation and PaO_2 concentration; its reported effects on apnea frequency, however, are variable, and in the absence of hypoventilation, progesterone probably has no major therapeutic effect (Lyons and Hyang, 1968; Orr et al, 1975). Decrease libido, impotence, and alopecia are major side effects that frequently limit its long-term usefulness. The carbonic anhydrase inhibitor *acetazolamide,* which stimulates ventilation by increasing the hydrogen ion concentration of arterial blood, has been reported to decrease apnea frequency, apnea-associate arousals, and the severity of oxygen desaturation in patients with central sleep apnea (Sutton et al, 1979; White et al, 1982). The effects of acetazolamie in patients with obstructive sleep apnea, however, have not yet been reprted. *Theophylline,* which increases hypoxic, but not hypercapnic, ventilatory drive in normal adults has been successfully used to treat apnea in premature infants, but a thorough stuy of its effects in adults with sleep apnea has not been reported.

Protriptyline, a nonsedating tricyclic antidepressant, prouces variable but generally beneficial clinical results in patients with mild to moderate obstructive sleep apnea (Clark et al, 1979). Protriptyline decreases the percentage of time spent in REM sleep, thereby reducing the severity of nocturnal hypoxemia by decreasing the frequency of the more severe REM-related apneas (Brownwell et al, 1982; Smith et al, 1983). Side effects of protriptyline that frequently limit its use include dry mouth, urinary retention, constipation, and impotence.

Although *oxygen therapy* has a well-established role in the treatment of hypoxemic patients with chronic lung isease, its role in the treatment of sleep apnea is more controversial (Nocturnal Oxygen Therapy Trial Group, 1980). It has been reported that the administration of oxygen has the adverse effect of prolonging apnea duration, thereby increasing the severity of hypercapnia and acidosis during both NREM and REM sleep (Motta and Guilleminault, 1978). Patients with an intact ventilatory drive may show severe CO_2 retention when nocturnal oxygen therapy removes the major stimulus maintaining ventilation.

The risk of hypercapnic acidosis mandates that all patients receiving nocturnal oxygen therapy be carefully monitored, although oxygen limited to a flow rate of 2 L/min usually improves nocturnal oxygen saturation with little risk of inducing serious hypercapnia, acidosis, or arrhythmias in the majority of patients. The treatment of such coexisting disorders as hypothyroidism, hypertension, congestive heart failure, and chronic lung disease, however, cannot be neglected.

Since respiratory efforts continue during obstructive apnea, various methods have been recommended to maintain upper airway patency uring sleep. *Nasopharyngeal intubation* at night has been successful in a few patients but is inacceptable, in terms of comfort, to a majority of patients. A *tongue-retaining device* that uses suction to hold the tongue in a protruded position has been somewhat successful, but discomfort also limits its practical widespread use (Cartwright and Samelson, 1982). A dental device is intened to eliminate the obstruction at the base of the tongue by advancing the manible forward while the patient is sleeping. This device is considered to have little influence on the soft palate and uvula. In one study the sleep splint produce a significant improvement in apnea index and the longest duration of apnea, oxygen saturation, and symptoms (Ichioka et al, 1991).

Nasal continuous positive air pressure (CPAP) is administered while the patient is asleep with a mask over the nasal area. This mask is connected via a tube to a device that produces a continuous positive airway pressure in the range of 7 to 15 cm of water. This pressure acts as a pneumatic splint and passively opens the airway to prevent the obstructive episodes (see Fig. 77-11). In many cases this technique is effective in eliminating obstructive apneic episodes, improving arterial oxygen saturation, and producing a decrease in daytime hypersomnolence. Its use over the past few years has increased. It may be used as the sole therapeutic measure or may be combined with surgery and weight loss. In some patients it is effective in relieving the sluggish feelings and thereby allows the patient to become more effective in a weight reduction and exercise program. It may also be used to allow the patient to sleep safely and to improve the cardiopulmonary status so that surgery can be safely performed at a later date. Patients who have had surgery for sleep apnea with poor results may find CPAP effective. Its disadvantage is that patients have to sleep with a mechanical device. Some patients simply do not tolerate the mask discomfort or the nasal dryness and congestion. Causes for discontinuation of CPAP therapy include insomnia; noise from the machine, poor mask fit, otitis media, and nasal mucosal irritation. The reported compliance rate of continued usage at home over many months varies from 53% to 83% (Kaplan and Staats, 1990). CPAP is commonly used as initial therapy in patients with no clinically apparent causes for obstruction because of the predictability of success, and lower costs and complication rate when compared to surgical therapy (Anand et al, 1991).

Surgical Management

Surgical therapy for obstructive sleep apne is designed either to bypass the obstructive area or to prevent collapse of the soft tissues at the obstructive site.

General anesthesia

General anesthesia management in these patients is frequently difficult. The combination of obesity and low oxygen saturation creates an increased risk of problems. These obese, short, thick-necked patients may be difficult to intubate, and in a reclining state the oropharyngeal tissues may collapse posteriorly, creating difficulty in ventilating these patients adequately by mask alone. Along with excessive tissues in the hypopharynx, the large mass of the tongue in these patients combined with the inflexibility of the thick neck may produce a difficult if not impossible situation for intubation. Supplemental inhaled oxygen may be used during light anesthesia before intubation. The use of oxygen may depress the ventilatory stimulus in these patietns, who may have a chronically low oxygen saturation. The routine use of paralytic agents before intubation may lead to further collapse of the airway and an inability to ventilate by mask or to intubate.

Intubations of these patients commonly are difficult, and the experienced anesthesiologist should be prepared to use an alternative technique of intubation, such as nasal intubation while the patient is awake or intubation using a fiberoptic telescope within the endotracheal tube. Preoperative sedation is not given, so that the respiratory drive is not further depressed. Unless an adequate airway is ensured, paralytic agents usually are not used. In some cases a long nasal hypopharyngeal tube may be inserted into the nose and down into the hypopharyngeal area just above the epiglottis to facilitate maintenance of an airway during intubation. During these intubations the surgeon and the operating room staff should be prepared for an emergency tracheotomy if intubation cannot be achieved and mask ventilation is inadequate.

Patients should only be extubated when fully awake. If the patient has had some type of oropharyngeal procedure, the endotracheal tube may be left in place longer than usual postoperatively to ensure an adequate airway. The tube may be removed in the recovery room or even left in place until the next morning depending on the alertness of the patient and the patency of the oropharyngeal airway. Patients with severe preoperative obstructive apnea may be treated with CPAP immediately after extubation and postoperatively to assist with airway patency and oxygen saturation. This treatment has been shown to be effective in maintaining oxygen saturation at levels of 90% when using CPAP on room air (Powell et al, 1988).

Intravenous sterois may be used during surgery and postoperatively to decrease the edema in the operative area. Postoperatively the respiratory drive may remain depressed because of the high PO_2 an low PCO_2 following anesthesia. The surgeon should be alert to the possibility of early postoperative extubation leading to obstruction and difficulty in ventilating with a mask, similar to what occurs during induction. Use of intraoperative narcotics should be avoided when possible. Sleep medication postoperatively is routinely withheld, and narcotics and hyponotics should be cautiously used during the postoperative period for fear of further respiratory depression. Patients with arrhythmias or low minimum oxygen saturation of their preoperative sleep study should be monitored for arrhythmias postoperatively.

Factors that predispose to postoperative airway problems and arrhythmias are lower minimum oxygen saturation and higher apnea index on the preoperative sleep study and the amount of intraoperative narcotic administration. Patients with intubation complications tend to be heavier, whereas patients with extubation complications receive more narcotic analgesia preoperatively (Esclamado et al, 1989).

Nasal surgery

Nasal obstruction may be a contributing factor to obstructive sleep apnea. Experience teaches us that even a simple cold with nasal obstruction leads to restless sleep. Although nasal obstruction may be a contributing cause, in most patients with significant obstructive sleep apnea, the nasal obstruction is not the major factor (Blakley and Mahowald, 1987). The nasal obstruction may be secondary to deviation of the nasal septum, narrowing of the angle between the septum and lateral nasal cartilages, nasal polyps, or hypertrophy of the turbinate tissues secondary to infection or allergies. If the patient and surgeon believe that the nasal obstruction may be a contributing factor, appropriate measures such as nasal septal reconstruction or nasal polypectomy or measures to reduce the size of the turbinates should be performed. Generally, it is unusual (unless the nasal obstruction is severe) that correction of a nasal septal deformity leads to an objective improvement of the quality of sleep in patients with significant obstructive sleep apnea. Frequently these procedures will relieve the symptomatic nasal obstruction, but objective evidence of improvement on a sleep study is usually not seen.

In some patients nasal surgery an oropharyngeal surgery are performed at the same time. Because nasal packing by itself can produce apnea even in healthy persons and can aggravate it in the patient with apnea, a less risky approach in some patients is to separate nasal and oropharyngeal operations into two stages allowing recovery from one before the other is unertaken (Fairbanks, 1990).

Pediatric tonsillectomy and adenoidectomy

It is not unusual that parents of children with enlarged tonsils and adenoids describe loud, sonorous respirations with retractions and restless sleep patterns. Many of these patients also have recurrent episodes of tonsillitis. In most cases removal of the tonsils and adenoids will result in symptomatic improvement in nighttime respirations (Kravath and Pollack, 1977). A few morbidly obese children with severe obstructive sleep apnea may require the more standard type of UPP. It is well known that adenotonsillar hypertrophy with upper airway obstruction may lead to cor pulmonale if not properly treated.

Uvulopalatopharyngoplasty

Uvulopalatopharyngoplasty (UPP) is designed to relieve oropharyngeal obstruction by excision of excessive soft tissue that involves the free margin of the soft palate, uvula, tonsils, and posterior pharyngeal wall (Shepard and Olsen, 1990). It was first described by Ikematsu (1964) for correction of snoring. It has been popularized by Fujita et al (1981) and Simmons et al (1983). The two factors generally used to determine the need for surgical intervention in sleep apnea patients are medical complications and the degree of socioeconomic difficulties caused by incapacitating hypersomnolence and excessive snoring. The decision regarding surgical therapy is made by a team of medical specialists and otolaryngologist - head and neck surgeons. When life-threatening cardiac arrhythmias are identified in association with an obstructive apnea, a tracheostomy should be performed, at which time UPP also may be consiered. If a UPP is concomitantly performed, the effectiveness of this surgical procedure can be evaluated after 6 to 8 weeks (when healing is complete) by repeating the sleep study with the tracheostoma occluded.

UPP should be considered and often can be performed safely without a tracheotomy in patients with less severe obstructive sleep apnea who do not respond to medical therapy. Such patients have to be monitored closely during the postoperative healing phase to ensure that postoperative swelling of the oropharynx does not lead to upper airway obstruction. For some patients with severe narrowing of the upper airway, intubation management during anesthesia can be a serious problem. In such patients a tracheotomy may be necessary at the beginning of the UPP procedure to maintain a safe airway during the early postoperative healing phase. After the patient has healed satisfactorily, the tracheotomy tube may be removed. Enlargement of the oropharyngeal airway has been demonstrated following the UPP by comparing preoperative and postoperative CT scans (Shepard et al, 1984). This has confirmed the significant enlargement of the oropharyngeal airway and is correlated with improvement of oxygen saturation and reduction of the total number of apneic episodes per hour.

During the UPP, the tonsils, if present, are excised, and excessive tissue along the posterior tonsillar pillar is removed (Fig. 77-12). Posterior tonsillar pillars are sutured anteriorly to the anterior tosillar pillar. This removes any excessive tissue and enlarges the oropharyngeal opening in the horizontal plane. The uvula is also excised, and a portion of the inferior edge of the soft palate frequently is removed. This area is then closed on itself, and the anterior wall of the nasopharynx, which is a posterior wall of the soft palate, is rotated anteriorly to enlarge the nasopharyngeal outlet into the pharynx. The resection of the uvula and portions of the palate enlarges the oropharynx in a vertical as well as a horizontal fashion, which results in a significant increase in the size of the oropharyngeal inlet (Figs. 77-6, 77-10, 77-13, and 77-14).

Fujita et al (1985) have reported in detail the postoperative results of this surgery. Before surgery their patients demonstrated the sleep disturbance characteristics of obstructive sleep apnea. The percentage of stage 1 sleep was elevated, and that of stage 2 sleep was reduced. Following surgery the percentage of stage 1 sleep was reduce and the percentage of stage 2 sleep was significantly increase. Preoperative and postoperative objective measurements of excessive daytime sleepiness (MSLT) were performed. (Short latencies are indicative of pathologic sleepiness. A normal adult falls asleep with the MSLT in 10 to 12 minutes, and sleep-deprived normal subjects fall asleep in 6 to 7 minutes.) Preoperatively the MSLT latency periow was 3.9 minutes, compared with 6.6 minutes postoperatively.

Although significant post-UPP improvements were found in the total group of patients, there was great variability in the degree to which patients responded. Patients were divided into responders and nonresponders, depending on the apnea index (number of apneic episodes per hour). The apnea inex was selecte as a key parameter, since it is the measurement used to mak the diagnosis of sleep apnea syndrome. Patients showing a minimum of a 50% reduction in apnea index were placed in the responder group, and all others were placed in the nonresponder grou. Half of the total number of operative patients were considered to be responers. The reduction in apnea index for responders to surgery ranged from 9.5% to 58.3% with an 84% reduction in apnea index. In nonresponders the mean duration of the apneic episodes remaining after surgery was significantly shorter than before surgery. The number of times oxygen saturation was below 85% decreased significantly in responders, but not as dramatically for nonresponders. There was no significant change in any sleep parameter for nonresponders. In contrast, the sleep of responders improved markedly following surgery. The percentage of stage 2 sleep increased significantly to a normal level, and the percentage of stage 1 sleep decreased significantly. Daytime sleepiness, as measured by the MSLT, increased significantly from 3.4 to 9.6 minutes in responders.

Generally, the variables that distinguish the responder from the nonresponder group were body weight and the oropharynx as the major site of airway compromise. All patients whose body weight was greater than 125% of the ideal body weight did not respond to UPP. The majority of patients at each level of body weight less than 125% of ideal body weight responded to the UPP. The majority of patients whose major site of airway compromise was the oropharynx responded to the surgery. The oropharyngeal obstruction included a large uvula, wide tonsillar pillars and mucosal folds, redundant posterior pharyngeal mucosa, and a low-arched soft palate. In contrast, the majorityu of the patients who had both oropharyngeal and hypopharyngeal abnormalities did not respond to surgery. Hypopharyngeal obstructions included a large base of tongue, omega-shaped epiglottis, and redundant aryepiglottic folds. It was demonstrated in this study that UPP decreased excessive daytime sleepiness, improved the quality of nocturnal sleep and respiration during sleep, decreased nocturnal hypoxemia, and reduced the number of apneic episodes per hour.

It is to be noted that in the nonresponder group, even though the apnea index was not significantly reduced, nocturnal oxygenation showed significant improvement in some cases, and a decrease in excessive daytime sleepiness was frequently noted. It has been my experience and the experience of other surgeons that patients undergoing UPP reported improvement in their symptoms whether they fall into the responder or nonresponder group as defined by the 50% reduction in apnea index. Postoperative questioning reveals that almost all patients are very pleased with the surgical results and would undergo the surgery again if given the option. Simmons et al (1984) reported similar results in 155 patients by showing that UPP is about 50% effective in curing or cosiderably decreasing sleep apnea.

Simmons et al (1984) reported that snoring was eliminated or much reduced in 93% of all their patients and in 95% of patients without serious obstructive sleep apnea. It is significant to note that in their series, two thirds of the patients with complaints of snoring and none of the classic symptoms of sleep apnea actually did have obstructive sleep apnea as demonstrated by the polysomnograph. Katsantonis et al (1990) reported that 86% of patients indicated that their snoring was either completely eliminated or markedly reduced. Pelausa and Tarshis (1989) reported elimination or improvement of snoring in 76% of their patients. It has been my experience that virtually all patients who have significant snoring report dramatic improvement in their symptoms following the UPP. The main complaint of patients who undergo UPP for snoring is postoperative pain, which usually persists for about 10 days but may linger for weeks.

The decrease in snoring and daytime sleepiness following UPP is most predictable. Less predictable is the ability to decrease the number of apneic events per hour and to improve the oxygen saturation (Zohar et al, 1991). In a study by Wetmore et al (1986), using a wide number of factors, 30% of postoperative UPP patients were judged markedly improved, 33% showed some improvement, and 36% were believed to have experienced no significant improvement. Another study has demonstrated that patients with more than 70 apneic events per hour experienced the most improvement (Caldarelli et al, 1986). In a study that judged success by decreasing the number of apneic episodes with oxygen saturation below 85%, 66% were good responders (Katsantonis and Walsh, 1985). It is now generally agreed that when reporting results of treatment that both the apnea-hypopnea index and some measure of oxygen deprivation should be used. A 50% improvement ni the apnea index, commonly used as a bench mark for improvement, is not necessarily reflective of oxygen desaturation (Simmons and Hochman, 1990). Sleep architecture and respiratory indices are improved in the majority of patients after UPP, particularly in the lateral sleep position (Katsantonis et al, 1990).

Computerized tomography confirmed the velopharynx to be the site of maximal preoperative narrowing in the majority of patients with obstructive sleep apnea. Maximal narrowing was observed at 10 and 20 mm below the level of the hard palate in 87% of patients. Uvulopalatopharyngoplasty produced maximal increases in cross-sectional area at these two levels in patients with successful results (Shepard et al, 1989).

It has been demonstrated that even in cases when UPP substantially reduces the frequency of obstructive apnea, some partial obstruction may persist. This persistent partial obstruction may be the key factor contributing to further pharyngeal narrowing and a recurrence of obstructive sleep apnea syndrome (Polo et al, 1989).

The obvious dilemma to overcome is to predict those patients who are going to be significant responders to UPP and those who will not respond adequately (Blakely et al, 1986). This is a difficult decision and one not easily answered. Despite careful preselection of patients for upper airway narrowing and collapse in the oropharynx, UPP does not always produce successful results. The reasons for failure in these patients are unclear, but they could include a poor technical result, persistent collapse at the same level, or shift in the site of collapse to another region. If the majority of the obstruction is occurring in the area of the oropharynx (tonsil-palate area), one can reasonably predict that the results of UPP will be good. However, if the major portion of the obstruction is occurring in the hypopharyngeal, base of tongue area, the results of UPP are less predictable (Gislason et al, 1988). Fluoroscopic studies of the oropharynx or hypopharynx during sleep have demonstrated that obstructions may occur predominantly in the oropharynx and hypopharynx or in a combination of multiple areas. To isolate a specific area of obstruction is, at times, impossible. In fact, in a large percentage of patients there are probably multiple areas of obstruction, and it may be shown in the future that a diagnostically important point is to distinguish the area that initiates the collapse. Once the initial site of collapse develops, all area of the oropharynx and hypopharynx may be prone to obstruction.

When the palate is modified in a UPP, there is a possibility of complications related to changes in palatal function. If the modification resection is excessive, palatal incompetence will result in nasal air leakage during speech and nasal regurgitation during swallowing

(Katsantonis et al, 1987; Thawley, 1985). Initially, during the early postoperative healing period, palatal incompetence will occur for several days to 2 weeks, but permanent significant palatal incompetence is unusual unless an excessive resection is performed (Fig. 77-15). Excessive resection particularly of the midline should be avoided. Palatal closure depends on the central mounding action of the musculus uvulae and on the lifting action of the levator palati muscles, which course from the eustachian tube downward (posteriorly) and medially to interdigitate in the midline. A midline defect, surgical or congenital, disrupts the function. Ideally the uvula should be shortened to a level slightly below the trailing edge of the rest of the shortened soft palate (Fairbanks, 1990).

An unusual complication may be the occurrence of nasopharyngeal-palatal stenosis (Fig. 77-16). This complication should be avoided at all costs, because it is difficult to correct. This is more likely to occur with excessive resection of the posterior tonsillar pillars, the excessive use of cautery, and undermining of the mucosa of the posterior pharyngeal wall (Katsantonis et al, 1987). Other factors may be wound dehiscence, infection, necrosis, scarring and nasopharyngeal packing, and the concomitant performance of an adenoiectomy (Thawley, 1985).

The UPP is designed to avoid nasopharyngeal stenosis. The incision lines should face forward, away from the nasopharynx. Excision should involve the anterior pillar (palatoglossal arch), not the posterior pillar. When the redundant posterior pillar is advanced laterally, forward, and upward (for suturing), the soft palate will be pulled forward along with it, and the nasopharyngeal space will be expanded. If the posterior pillar were to be excised, then the anterior pillar and the soft palate would be pulled backward (either by suturing or scarring), and the nasopharyngeal space would become narrowed or stenotic. Injury to the posterior pharyngeal membranes, either by undermining of cautery, is best avoided altogether. Passavant's ridge should be left uninjured. If adenoidectomy is necessary, the greatest of care should be taken to avoid any injury to the posterior (nasal) surface of the soft palate (Fairbanks, 1990).

Patients may complain of mild dryness in the throat and a sensation of persistent mucus in the oropharynx. This may be caused by decreased flow of nasal secretions over the scarred inferior edge of the soft palate.

Midline glossectomy

Midline glossectomy involves laser resection of the midline of the base of the tongue. This has been performed primarily on patients who have failed UPP and who were considered to have significant hypopharyngeal collapse on physical examination and Muller's maneuvre. Only 12 patients have been reported. Improvement in the apnea index occurred in 42%. Responders tened to be more retrognathic and less obese than nonresponders (Fujita et al, 1981). The possible complication rate would be predicted to be high unless patients are properly selected and the surgical technique is correct. The possible compilcations include bleeding and swallowing and speech problems. Although this technique may have applicability in the future more results need to be reported before this technique is widely recommended.

Mandibular advancement techniques

It has long been recognized that conditions associated with a receding mandible predispose to the development of sleep apnea. This may occur in pediatric patients who have the Pierre Robin syndrome, and it occurs in older patients who have a somewhat small, retrognathic mandible. This retrognathia may be congenital or acquired through trauma or iatrogenic means. It has been reported following partial mandibular resection for tumors (Panje and Holmes, 1984). Most of these patients have nonobtuse mentocervical angle (neck-to-chin angle), a chin deficiency, and usually a class II dental malocclusion. The tongue posture is more posterior, since the genioglossus muscles are not attached as far anterior as in patients with normal occlusion and mandibular position. The tongue position in the oropharynx, which is determined partially by the function of the genioglossus muscle and is related to the position of the mandible, may be an important consideration in patients who have obstruction in the base of the tongue-hypopharyngeal area (Wickwire et al, 1972). This problem has been addressed by advancing the mandible anteriorly (Dierks et al, 1990). Patients who are candidates for this procedure may or may not have obvious mandibular retrognathism on clinical examination. Cephalometric radiographic studies should be performed on all patients who are considered potential candidates for this approach (Burstone et al, 1978; Riley et al, 1983). Cephalometric radiographic analysis should confirm the retrognathic position of the mandible and should demonstrate a narrowing of the hypopharyngeal airway (Tilkian et al, 1976).

Several surgical procedures have been described and reported to treat receding mandibles. One is total mandibular advancement, and another is a more isolated anterior mandibular advancement with myotomy of the infrahyoid muscles and anterior hyoid advancement. Total mandibular advancement consists of bilateral bony cuts in the area posterior to the last molar (Fig. 77-17). This is done bilaterally, and the entire anterior segment of the mandible is advanced anteriorly. Preoperatively an acrylic splint is made to recreate the predicted normal occlusion, and the anterior advanced portion of the mandible is wired into position and held in intermaxillary fixation by wiring the mandible to the splint and then attaching all of this to the maxilla. Healing takes place over a period of 6 weeks, and intermaxillary fixation is required during that period of time. When healing is complete, the wires and splint are removed, the mandible is positioned more anteriorly, and this in turn pulls the genioglossus muscle and the tongue more anteriorly, thus enlarging the hypopharyngeal cavity (Powell and Guilleminault, 1983).

This surgery has been successful in a limited number of patients. These patients must have documented retrognathic mandibles to be expected to improve from this surgery. In some cases, this surgery has been performed in patients who have failed to respond to the previously described UPP. In other patients with obvious retrognathia, the surgery has been done primarily without any other procedure. Experience with this procedure is not as large as with UPP; thus fewer postoperative patients have been studied extensively to document clinical improvement objectively. Problems with this are the need of intermaxillary fixation and the resultant change in dental occlusion.

Inferior sagittal osteotomy of mandible with hyoid myotomy an suspension

Riley et al (1986) recently described a mandibular technique in which an anteroinferior sagittal osteotomy is performed to include the geniotubercle on the inner cortex. This is the site of attachment for the genioglossus muscle. This procedure involves forward advancement of the anteroinferior portion of the mandible, maintenance of the general continuity of the mandible, and repositioning of the genioglossus-attached segment of the mandible more anteriorly (Fig. 77-18). This theoretically should pull the tongue forward and improve the hypopharyngeal airway. Concomitantly with this procedure, the infrahyoid muscles are transected, allowing the hyoid bone to be pulled more anteriorly and superiorly. This bone is held in position by attaching it with pieces of fascia to the remaining intact mandible. Although the number of patients on which this procedure has been performed is small, postoperatively the patients had fewer symptoms of obstructive sleep apnea. The long-term results of inferior sagittal osteotomy are as yet unknown. This procedure has the advantage of obviating the need for intermaxillary fixation, and it does not affect dental occlusion. Surgical results of this procedure were reported in patients with normal pulmonary function, normal manibular skeletal development, and the absence of morbid obesity. Polysomnography revealed that 67% had responded to the surgical treatment and 33% had not.

Maxillary, mandibular, and hyoid advancement

A LeFort I maxillary osteotomy advancing the maxilla forward is combined with mandibular advancement and hyoid suspension (Riley and Powell, 1986). The results of this surgery were reported in 25 patients who were selected for morbid obesity, severe mandibular deficiency, and failure of other surgical procedures. All patients showed good results (Riley et al, 1989).

Hyoid expansion

Hyoid expansion is an experimental surgical proceure in which the hyoi is separated into three pieces: one anterior and two lateral. These segments are then wired to an arch-bar type of device, which holds the segments in an expanded fashion, thus enlarging the hypopharyngeal lumen. This serves to stent the airway open and to prevent airway collapse in the face of negative pressure (Fig. 77-19) (Patton and Thawley, 1983). Although effective as an experimental model, it has not been shown to be consistently effective in patients with obstructive sleep apnea.

Tracheotomy

Tracheotomy bypasses the upper airway obstruction and is known to reverse the obstructive components of obstructive sleep apnea. Tracheotomy is indicated for this condition if the apnea is severe and if conservative therapy, including weight loss, removal of obstructive tissue, avoidance of sedatives, and nasal CPAP, has failed to change these symptoms significantly. Generally, the indications for tracheotomy in obstructive sleep apnea are cor pulmonale, chronic alveolar hypoventilation, serious nocturnal arrhythmias, and disabling hypersomnolence, if these symptoms have been unresponsive to attempted weight loss and avoidance of sedatives and alcohol and if the patient has not responded or tolerated a trial of nasal CPAP.

The immediate improvement in symptoms after tracheotomy is dramatic. Its effectiveness in controlling cardiac arrhythmias and improving symptoms of pulmonary hypertension and oxygenation is well documented (Walsh and Katsantonis, 1984). The disappearance of marked sinus arrhythmia and extreme sinus bradycardia, as well as atrioventricular block after tracheotomy, and their reappearance during sleep if the tracheostoma has been occluded indicate that these characteristic rhythm disorders are directly related to the airway occlusion during sleep. Tracheotomy also changes the sleep patterns in these patients. Following tracheotomy there is an almost immediate reversal of excessive daytime sleepiness and frequent sleep periods during the day (Weitzman et al, 1980). The marked improvement in the nocturnal sleep pattern is due to a major reduction in the frequency of transient awakenings. There is also a decrease in the number of stage changes and the establishment of periods of sustained sleep, especially in stages 3 and 4. The tracheotomy reverses the frequency of transient awakenings. The tracheotomy reverses the fragmentary unsustained sleep stage organization that is associated with marked decreases in stage 3 and 4 sleep in patients with obstructive sleep apnea. Oxygen saturation is usually improved after tracheotomy. The obstructive and mixed-type apneas are essentially eliminated by tracheotomy, and although nonobstructive apneas and hypopneas may persist and may even initially increase, usually after 3 to 4 weeks they will return to their normal pattern. It is therefore clear that tracheotomy is a very effective treatment for the patient with severe obstructive sleep apnea.

The decision regarding tracheotomy is made by a team of medical specialists and otolaryngologists-head and neck surgeons. When life-threatening cardiac arrhythmias are identified in association with an obstructive apnea, tracheotomy should be performed. The other main indication of tracheotomy is severe hypoventilation with a marked decrease in arterial oxygen saturation. At the time that the tracheotomy is performed, consideration may be given to performing a concomitant UPP if this is clinically indicated. If the patient is severely obstructed and the cardiac status is very tenuous, tracheotomy may be performed, followed by appropriate medical, cardiac, and pulmonary therapy. After the patient has stabilized weeks later, he or she may be returned to the operating room for a UPP. Some surgeons elect to perform a tracheotomy on patients undergoing UPP in order to maintain a safe postoperative ariway. Once the patient has satisfactorily healed over a period of a few days, the tracheotomy tube may be removed quickly. Generally, if a tracheotomy is performed concomitantly with a UPP, the tube is left in place for approximately 6 weeks, at which time a repeat sleep study is performed with the tracheostoma unplugged and plugge to determine the effectiveness of the UPP. If there has been satisfactory improvement in the sleep study parameter with the tracheostoma closed, the tracheotomy tube is removed. If significant cardiac problems persist or if there is significant remaining daytime sleepiness and disturbed sleep patterns, the tracheotomy tube is left in place (Wetmore et al, 1986).

Usually the tracheotomy is performed with the patient under general and endotracheal anesthesia. The induction of anesthesia may present problems, since excessive tissue in the oropharynx may make it difficult for the anesthesiologist to intubate the patient. If the patient can be safely ventilate and intubated, routine induction of anesthesia with muscle relaxation is performed. However, if there is a question about the ability to ventilate the patient after muscle relaxation, the anesthesiologist may elect to perform intubation with the patient awake and under topical anesthesia. This may be performed by direct laryngoscopy through the oral approach, or the trachea may be intubated by using a fiberoptic irect scope that has been threaed down an endotracheal tube. This may be performed orally or transnasally. Tracheotomy may in some instances be performed using local anesthesia. Generally, this is not recommended, however, because there is usually a large amount of excessive tissue in the surgical field. Tracheotomy in these requires a significant amount of manual manipulation in the neck area. The time required for tracheotomies in these extremely obese patients with short necks is typically much longer than that for a routine, simple tracheotomy in a normal-weight or thin patient.

Several different types of tracheotomy techniques are available. The simple tracheotomy technique consists of a midline incision with dissection deep to the anterior wall of the trachea. A vertical incision is performed in the second or third tracheal ring, and a standard tracheotomy tube is placed. If the patient is not excessively obese, this technique may be satisfactory. However, most of these patients are obese with thick necks, and this technique commonly leads to problems. The problems associated with the performance and care of the standard tracheotomy in obese patients may be significant. The surgical performance of the technique may be quite difficult, since there are large amounts of fatty tissue that may interfere with exposure of the trachea. The trachea may be very deep in the neck, and the proper fitting and maintenance of a standard tracheotomy tube in such a deep trachea may be very difficult. In obese patients, granulation tissue commonly forms in the tracheostoma site (Fig. 77-20). This seems to be related to the large surface area of fatty tissue that is exposed (Conway et al, 1981). This seems to be related to the large surface area of fatty tissue that is exposed (Conway et al, 1981). This may also lead to granulation tissue within the trachea, may require repeated removal an treatments, and may, on occasion, even lead to obstruction of the airway. If the patient coughs out the tracheotomy tube during the early postoperative period, it may be difficult, if not impossible, to reinsert the tube quickly enough through the excessive amounts of tissue. To reduce these complications, many surgeons now perform a modified tracheotomy that allows resection of large amounts of fatty tissue at the tracheostoma site and the creation of skin flaps that funnel down to the trachea (Fig. 77-21) (Fee and Ward, 1977). This permits easier and safer care of the tracheostoma site; it essentially connects the skin to the trachea wall and eliminates the exposure of the fatty tissue to the air (O'Leary and Farrell, 1986). The amount of granulation tissue is dramatically decreased, and there is greater ease in safely maintaining a tracheotomy tube in place. The actual incision into the trachea may be a simple vertical one, or an inferior or superior flap of anterior tracheal wall may be rotated to the skin surface. Although this tracheotomy technique is better suited for permanent use, the procedure may be satisfactorily reversed with closure of the tracheostoma.

Although tracheotomy is an effective therapeutic method for patients with significant obstructive sleep apnea, the performance, postoperative care, and long-term follow-up require an active understanding of the potential problems. The major tracheal complications are granulation, tissue formation, bleeding, stoma narrowing, bronchitis, pneumonia, and psychologic stigmata. Granulomas may form at the upper margin of the stoma site, secondary to chronic irritation and infection from the tube. The sharp edges of the tube rubbing against the anterior tracheal wall can aggravate the inflammation. The standard tracheotomy leaves fatty tissue that is easily inflamed and consequently tends to form granulation tissue, resulting in bleeding and local infection. When the skin flap technique is used, it keeps the stoma patient more easily and provides skin coverage of the fat, decreasing inflammation and granulation tissue formation. It also diminishes the need for a long intratracheal prosthesis. Granulation tissue may be increased secondary to chronic bronchitis, which aggravates inflammation at the stoma site; however, the development of tracheal granulation seems to be directly related to the type of tracheotomy performed and less to the chronic bronchial pulmonary disease.

There may be postoperative wound infections with bronchitis and occasional pneumonia. The complication rate is significantly reduced by debridement of the excessive fatty tissue and the use of local skin flaps. Recurrent purulent bronchitis seems to occur more in patients who are predisposed to pulmonary infections because of associated chronic lung disease. Many of these patients continue to smoke. Bronchitis and pulmonary infections increase if patients fail to use humidifiers at night, which results in inspissated bronchial secretions.

Psychosocial probelms may develop following a tracheotomy. It is not unusual for patients to be depressed during the initial early postoperative period. This usually resolves with supportive care and through the patient's active understanding and management of the tracheostoma.

Although major depression and personality changes related to sleepiness respond to tracheotomy, the tracheotomy may produce transient adjustment reactions, spousal rejection, and increased dependency. Although tracheotomy in these patients produces more problems than the standard type of simple tracheotomy in other patients, these patients can be satisfactorily handled if their problems are anticipated and adequately treated. The results are improved through a thorough, perioperative teaching program aimed at educating the patient as well as the spouse and other family members regaring care of the tracheostoma.

Summary

Surgical therapy remains a viable alternative for treatment of obstructive sleep apnea patients who are unresponsive to more conservative medical management. There are multiple options available for surgical therapy, with the UPP being the most widely employed at the present time. However, active, basic, and clinical research is ongoing, and our concepts of pathophysiology and treatment continue to evolve.