determinations show hypoxemia and hypercapnia, and blood cell counts may indicate polycythemia. Although rare, hypothyroidism, acromegaly, and amyloidosis can cause or enhance OSA, and these conditions should be considered.

The diagnosis of OSA requires overnight polysomnography, during which continuous recordings of electrocardiographic and electroencephalographic tracings are made while the patient sleeps. Airflow, oxygen saturation, and respiratory, eye, chin, and limb muscle movements are monitored and recorded. OSA is diagnosed in sleeping patients (confirmed by electroencephalographic tracings) who develop cessations or reductions of airflow despite repeated muscular efforts to breathe (E-Fig. 19-1). These episodes may be accompanied by transient hypoxemia and cardiac arrhythmias. A score (i.e., apnea-hypopnea index) is derived from these data that defines OSA.

Polysomnography can distinguish OSA from central sleep apnea, during which cessation of airflow is associated with halted respiratory movements. Polysomnography is also important to rule out other sleep disturbances caused by insomnia, narcolepsy, parasomnias, and periodic limb movement syndrome. For patients strongly suspected of having OSA, home sleep studies that measure airflow, oxygen saturation, and chest and abdominal muscle movements (with or without an electroencephalogram) are frequently effective in making the diagnosis of OSA (level 1 evidence). However, if the diagnosis is unclear or there is concern about narcolepsy or some other sleep disorder, formal polysomnography in the laboratory is needed.

### Treatment

Treatment of sleep apnea includes behavioral and medical approaches. When associated with obesity, significant weight loss (through lifestyle modification or bariatric surgery) results in a reduction in the apnea-hypopnea index (level 1 evidence). Avoidance of sedatives and alcohol are also encouraged (level 3).

Airway obstruction can be prevented with the use of CPAP provided through a tightly fitted mask (level 1 evidence). CPAP maintains positive airway pressure throughout expiration, thereby preventing collapse of the upper airway. The amount of airway pressure can be titrated, and oxygen can be added if necessary. Many patients are begun on autotitrating CPAP; the machine senses apneas and increases CPAP automatically to eliminate them. Autotitrating CPAP is not inferior to a fixed CPAP prescription, based on in laboratory polysomnography (level 1). CPAP is effective in most patients, but compliance with this technique varies.

Surgical removal of obstructing tonsils, adenoids, and polyps or uvulopalatopharyngoplasty may be useful in patients with specific anatomic abnormalities. However, in children with OSA, adenotonsillectomy was not superior to watchful waiting in improving neuropsychological function (level 1 evidence). Mandibular advancement may improve symptoms of OSA in patients who do not tolerate CPAP (level 3). A permanent tracheostomy may be necessary in severe cases after other approaches have failed. However, the surgical approach to this disorder is limited to selected patients only after CPAP has failed. The obesity-hypoventilation syndrome is treated effectively with noninvasive ventilation with bilevel positive airway pressure (level 2-1).

## OTHER DISORDERS RELATED TO RESPIRATORY CONTROL

Congenital central hypoventilation syndrome is a rare disorder that usually is diagnosed in infancy. It is caused by mutation in the *PHOX2B* gene (level 1 evidence).

Central sleep apnea is also a rare disorder. It predominates in men and is usually associated with normal body habitus. Patients may complain of daytime sleepiness and insomnia with frequent awakenings. The disorder is caused by apnea or hypopnea resulting from a decreased central respiratory drive. It may be a consequence of central nervous system injury (e.g., structural abnormality of the brain stem), or it may be idiopathic. Affected individuals may hypoventilate even while awake, although they are capable of normal voluntary breaths. During sleep, frequent apnea is common.

In patients with obstructive lung disease, increased work of breathing eventually makes it difficult to maintain sufficient ventilation to maintain normal $Paco_2$ levels. When ventilatory capacity declines, hypoventilation causes $Paco_2$ to increase; the kidneys respond by retaining bicarbonate to keep arterial blood pH at normal levels. These patients appear to have normal ventilatory drive, but they lack the ability to increase minute ventilation to meet increased metabolic demands. This characteristic is observed in certain patients with chronic bronchitis who exhibit the classic signs of the "blue bloater."

Lower brain stem and upper pontine lesions may cause *central hyperventilation.* However, this disorder rarely occurs in the absence of other physiologic or chemical abnormalities. Hepatic cirrhosis and extreme anxiety are causes of central hyperventilation. Pregnancy can also cause hyperventilation due to elevated levels of progesterone and other hormones. *Apneustic breathing* consists of sustained inspiratory pauses, resulting from damage to the midpons, most commonly caused by basilar artery infarction. *Biot respiration* or *ataxic breathing* is a haphazardly random pattern of sleep and is characterized by shallow breaths. A disruption of the respiratory rhythm generator in the medulla causes this sign.

The regular cycling of crescendo-decrescendo tidal volumes, separated by apneic or hypopneic pauses, characterizes Cheyne-Stokes respiration. Patients with this disorder usually have generalized central nervous system disease or congestive heart failure. Heart failure prolongs circulatory times, causing a delay between changes in blood gases at the tissue level and the arrival of those changes at the brain stem chemoreceptors. This delay sets up a cycle of gradual increase to hyperventilation, followed by gradually decreasing ventilation to apnea and then a repetition of the cycle. Studies suggest that OSA and Cheyne-Stokes respiration are consequences of congestive heart failure and contribute to its progression.

*For a deeper discussion on this topic, please see Chapter 86, "Disorders of Ventilatory Control," in* Goldman-Cecil Medicine, *25th Edition.*

## PROSPECTUS FOR THE FUTURE

With more than 5% of the population in the United States suffering from sleep-disordered breathing and with the recognition