Swallowing as a Protective Reflex for the Upper Respiratory Tract
Takashi Nishino, M.D.

IN humans, the pharynx serves as a common pathway for both respiration and digestion so that a reciprocal interplay between these two functions occurs at the pharynx. The swallowing reflex is one of the most important functions subserved by the pharynx. Although the main function of swallowing is the propulsion of food from the oral cavity into the stomach, it also can serve as a protective reflex for the upper respiratory tract by: (1) removing particles trapped in the nasopharynx and the oropharynx, (2) returning materials refluxed from the stomach into the pharynx, or (3) removing particles propelled from the upper respiratory tract back into the pharynx. Therefore, in the absence of adequate activity of the swallowing reflex, the chance of pulmonary aspiration is greatly increased. Pulmonary aspiration is a major complication to anesthesia for general surgery and a life-threatening danger to every comatose and debilitated patient. This review describes basic characteristics, the function of the swallowing reflex as a protective reflex for the upper respiratory tract, and some clinical problems related to swallowing disorders.

Basic Characteristics

Anatomic and Physiologic Considerations
The pharynx extends from the larynx upward to the base of the skull. The space is divided into the nasopharynx, the oropharynx, and the hypopharynx (fig. 1). These cavities are enclosed in a muscular cone and mucosa. Three constrictor muscles (superior, middle, and inferior) form the principal muscular elements of the pharyngeal wall and contract successively in swallowing to drive a bolus into the esophagus.

The tongue, epiglottis, and larynx are immediately anterior to the pharynx. In its resting state, the hypopharynx is an open cavity, a portion of the respiratory tract communicating with nose and larynx. There are considerable variations in anatomy during development from infancy to maturity. Thus, the infant larynx is located at the level of C3–C4, and with age and further development, the larynx eventually rests at the level of C4–C5 in the adult. The esophagus is anatomically simpler than the pharynx, with many mammals possessing an inner circular layer of muscles surrounded by an outer longitudinal layer. In humans, the upper one-third portion of the esophagus is striated muscle and continues the muscular pattern of the pharynx as it is held in position by its continuity with the pharynx. The lower two-thirds of the esophagus is stabilized by

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Address reprint requests to Dr. Nishino: Head, Department of Anesthesia, National Cancer Center Hospital East, Kashiwanoha 6-5-1, Kashiwa-shi, Chiba 277, Japan.

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fascia and by penetration through the diaphragm; the musculature of this portion is nonstriated. In general, swallowing can be divided into three stages: (1) the oral preparatory stage, in which a bolus of food is voluntarily squeezed or rolled posteriorly by pressure of the tongue upward and backward against the palate; (2) the pharyngeal stage, which is involuntary and constitutes the passage of food through the pharynx into the esophagus; and (3) the involuntary, esophageal state, which promotes passage of a bolus of food from the pharynx to the stomach. During the preparatory stage, muscles such as the medial pterygoid, masseter, and temporalis are often activated. Facial muscles also can be recruited to ensure development of anterior seal and stabilization of the mandible. The initiation of swallowing to a large extent depends on peripheral afferent inputs; in fact, swallowing is difficult in the absence of any material, solid or liquid, within the oral cavity. Thus, the voluntary command might be thought of as causing a gate to open in the brain that allows food or saliva, for example, to trigger the event reflexively. Of the three stages, the involuntary control of the pharyngeal stage of swallowing is the most important stage from the standpoint of the control of respiration, because swallowing and respiration share the pharynx as a common pathway. During the pharyngeal stage of swallowing (fig. 2), the soft palate is pulled upward to block the nasopharynx, and the tongue and lips close the mouth. The tongue rolls posteriorly on the hyoid bone, pushing the bolus of food backward between the tongue and the soft palate. The entire larynx is pulled upward and forward by muscles attached to the hyoid bone while the larynx closes the airway and respiration ceases momentarily.

At the same time, the hypopharyngeal sphincter around the esophageal entrance is relaxed and the superior constriction muscle of the pharynx contracts, giving rise to a rapid peristaltic wave passing downward over the pharyngeal muscles and into the esophagus. The pharyngeal stage of swallowing is completed when the soft palate returns to its original position and the larynx is reopened for respiration.

Neurophysiologic Regulation of the Swallowing Reflex

The act of swallowing requires not only the integrated action of the respiratory center and motor functions of multiple cranial nerves but also the coordination of the autonomic system within the esophagus. The swallowing reflex, like many other respiratory and cardiovascular reflexes, has a reflex system consisting of an afferent arc, the coordinating center, and an efferent arc. The neural organization of the swallowing reflex is schematically illustrated in figure 3.

Afferent Arc. The receptive regions eliciting the swallowing reflex have been investigated in several studies. It is now clear that the receptive regions include the soft palate, uvula, dorsal surface of the tongue, pharyngeal surface of the epiglottis, fauces pillars, glossoepiglottidinal sinus, dorsal pharyngeal wall, and the pharyngo-oesophageal junction. Of these regions, the fauces pillars are the most sensitive region in humans, whereas the soft palate and uvula are the least sensitive. Receptors that initiate swallowing have

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not been identified histologically. However, specific fluid or water receptors and some slowly adapting pressure receptors are distributed unevenly over the pharyngeal and laryngeal regions. These receptors can respond to water and light touch and probably initiate swallowing.

Miller and Sherrington\textsuperscript{12} ranked several liquids in terms of the sensory stimuli effective in eliciting the swallowing reflex. They showed in the cat that 20% alcohol was the most effective, then water, followed by saline, and mercury. Oil elicited no swallowing. The latter finding is in agreement with the clinical finding that oils are often aspirated into the bronchi without elicit ing the swallowing reflex.\textsuperscript{13} Primary afferents from the receptors in the oropharyngeal mucosa travel in the trigeminal (V), glossopharyngeal (IX), and vagus nerves (X), respectively, and converge in the solitary tract destined for synaptic contact with second-order neurons in the nucleus tractus solitarius (NTS). The NTS is not only an afferent portal but has interneurons that perform a more complex level of swallowing control. Control over the rate of reflexively induced swallowing occurs in the intermediate network at the level of NTS.\textsuperscript{14} The NTS also is richly endowed with neuropeptides and other neuroactive substances.\textsuperscript{15–18} Bieger \textit{et al.}\textsuperscript{19,20} demonstrated that microinjections of a small amount of dopamine into the preoptic area of the rat produce continuous swallowing and that systemic administration of L-DOPA not only produces repetitive swallowing but also enhances the reflexively evoked swallowing response. In contrast, an inhibitory effect was produced by microinjection of norepinephrine and the \( \alpha_2 \) agonist clonidine, as well as by microinjection of dopamine and its agonist, apomorphine, into the NTS.\textsuperscript{21}

Glutamate is found in very high concentrations in brain, particularly in the NTS.\textsuperscript{15} Although glutamate has not been implicated directly in swallowing, it has been reported that microinjection of small quantities of glutamate or glutamate-like agents into the NTS induces swallowing.\textsuperscript{22,23}

The discovery of opiate receptors and endogenous peptides with opioid properties provides an understanding of the mechanisms of morphine-induced respiratory depression. Although several types of opiate

\begin{figure}
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\includegraphics[width=\textwidth]{fig3.png}
\caption{Schema of neural pathways for the swallowing reflex. Broken line represents peripheral feedback. NTS = nucleus tractus solitarius.}
\end{figure}
receptor have been found in the NTS, the precise function of opioid peptide-containing neurons in NTS is unclear. However, they have been shown to produce an inhibition of respiration and related reflexes such as tongue protrusion, jaw opening, coughing, and swallowing. Therefore, it is possible that opioid peptides can play some roles in modulating the swallowing reflex.

Serotonin is another substance known to modulate the swallowing reflex. Although administration of serotonin into the fourth ventricle induces swallowing, microinjection of this substance into the region of the NTS and electrical stimulation of brainstem nuclei containing serotonergic neurons inhibits reflex swallowing.

Swallowing Center. So far there has been no evidence to suggest that the swallowing center resides within the NTS. Nevertheless, extensive evidence supports the existence of a swallowing center within the brain stem. The study of Dotty et al. indicates that the essential components for organizing the motoneuronal pattern of activity in swallowing lie in the reticular substance of the medulla about 1.5 mm from the midline, 1–3 mm dorsal, and just rostral to the rostral pole of the inferior olive. More recently, Holstege et al. suggested that, in the cat, part of the swallowing center might be present in the pontine tegmental area just dorsomedial to the superior olivary complex. However, this postulation does not agree with the experimental fact that only stimulation of the NTS and the adjacent reticular formation could elicit swallowing.

Efferent Arc. The motor nuclei involved in swallowing are the trigeminal (V), facial (VII), ambiguus, and hypoglossal (XII) nuclei. However, only a relatively small portion of trigeminal and facial nuclei participate in normal swallowing. In contrast, both ambiguus and hypoglossal nuclei activate all of their motoneurons during the act of swallowing and are considered to be the most important motor nuclei involved in this function.

Descending Cortical and Subcortical Influences. It is well established that the swallowing center receives descending influences from the cerebral cortex and subcortical areas. Descending fibers from the frontal cortex have been found histologically to terminate in widespread areas in the reticular formation of the brain stem. Sumi has demonstrated that electrical stimulation of the anterolateral cortical region increases the number of pharyngeal swallows elicited by stimulation of the superior laryngeal nerves. This evidence indicates that the cerebral cortex and subcortex areas and their interaction with brain stem can play an important role in the neural regulation of swallowing.

Peripheral Feedback. The central control of swallowing in the pharyngeal or esophageal stages is modified by peripheral feedback from the pharyngeal, laryngeal, and esophageal regions, which are richly supplied with sensory receptors that are active during the act of swallowing. For instance, detailed analysis of the amplitude and duration of electromyographic activity of the genioglossus and geniohyoides of humans indicates that the more dense the consistency of a bolus, the longer the duration of activity in the two muscles. Also, the studies of Mannson and Sandberg suggested that sufficient stimulus of the pharyngeal and laryngeal regions was needed to repetitively elicit swallowing and that peripheral feedback facilitated the voluntary elicitation of the swallow. Sumi also suggested that any procedure such as topical spray of local anesthetics, muscle paralysis, and mechanical injury that alters the peripheral feedback, may result in impairment of swallowing. Thus, peripheral feedback seems to modify the duration and intensity of individual muscles during swallowing and may even maintain a general facilitative level of the swallowing center.

Protection of the Airway
Swallowing results in reflex closure of the glottis and has an obvious protective value against the aspiration of foreign materials into the respiratory tract. Closure of the glottis during swallowing is the single most vital function of the larynx. Strong adduction of the true vocal cords is supplemented by the closure of the false cords and approximation of the aryepiglottic folds, although adduction of the true cords alone suffices to prevent entrance into the trachea of that which is swallowed. As a result, a bolus is shunted to either side of the larynx into the pyriform sinuses from which it passes into the esophagus. In humans, it has long been recognized that the epiglottis does not have an essential lid-like action preventing entrance of food into the larynx and that it makes no real contribution to swallowing. However, the epiglottis facilitates passage of a bolus past the larynx through the pyriform fossae and into the esophagus.

Interaction of Swallowing and Respiration
Swallowing must interact with respiration so that a swallow causes minimal or no disturbance of continual

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respiration. In awake human adults, approximately 80% of swallows occur during the expiratory phase, and respiratory movement resumes after a swallow in the same expiratory phase as has been interrupted. By contrast, in unconscious adult human, swallows occur with equal incidence during the inspiratory and expiratory phase, suggesting that the preponderant coupling of swallows with the expiratory phase may be associated with consciousness. The preponderant coupling of swallows with the expiratory phase may be a useful mechanism for clearing airway of foreign materials before the subsequent inspiration and thus may exert a physiologic role in preventing low-grade recurrent aspiration.

In infants, there is a marked alteration in breathing pattern accompanied by a marked depression of ventilation during feeding. Occurrence of cyanosis during feeding is not an uncommon event among infants, especially in the immediate neonatal period. Mathew et al reported a high incidence of apnea and bradycardia during oral feeding in healthy term neonates. With continued feeding, these infants recovered spontaneously. During eating and drinking in adults, the pattern of breathing becomes irregular, and this may increase the work of breathing. Although this is unlikely to have any consequences in normal subjects, it may be important in subjects with lung diseases and contribute to the dyspnea on eating noted by some people with respiratory disease.

In human infants, Wilson et al. have reported that prolongation of the respiratory cycle generally was observed when a swallow interrupted expiration at high lung volume, i.e., in late inspiration or early expiration. They suggested that Hering-Breuer inflation reflex or other lung-volume-related reflexes might inhibit the onset of inspiration subsequent to a swallow, whereas no such effect was observed in adult humans. The difference between infants and adults may be related to the fact that, in adults, the Hering-Breuer inflation reflex does not operate at normal tidal volume. Mechanisms integrating swallowing and respiration have been studied in animals of various ages. These studies revealed that, in newborn animals, the neural organizations of swallowing and respiration are immature and incompletely separated. Therefore, it is conceivable that vagally mediated respiratory reflexes and swallowing are more closely interlocked with each other in infants than in adults.

Although changes in $P_{aCO_2}$ and $P_{aO_2}$ are known to influence the level of respiration, the effects of these factors on swallowing reflex have not been studied fully in animals and humans. However, it has been shown that in the vagotomized, paralyzed cat, graded hypoxia results in a graded inhibition of the swallowing reflex, but graded hypercapnia has no effect on swallowing. A similar effect of hypoxia on the swallowing reflex was reported in the study of Sumi, which showed that in the decerebrated cat, during asphyxia, the hypoglossal motor neurons that discharge rhythmically in phase with respiration did not demonstrate a swallowing response to stimulation of the oropharyngeal cavity. Hypoxemic inhibition of the swallowing reflex also has been demonstrated in fetal sheep.

The mechanism of the depressant effect of hypoxia on the swallowing reflex remains elusive. However, a direct depressant effect of hypoxia on the central nervous system has to be considered as a possible factor of depression of the swallowing reflex during hypoxia. It is possible that, as with anesthesia, hypoxia depresses the swallowing reflex in humans and enhances the chance of aspiration of regurgitated material.

Pathophysiology of Swallowing Disorders

Depression of the Swallowing Reflex

Impairment of reflex swallowing may result from a defect or disorder in any part of the reflex arc of the swallowing reflex (fig. 3, table 2).

It is a commonplace clinical observation that, after the use of local anesthetics in the oropharyngeal region, some patients complain of dysphagia, indicating the impairment of triggering reflex swallowing. Although this type of impairment of swallowing reflex is considered to be due chiefly to blocking of sensory receptors, there is some evidence to suggest that the impairment of a peripheral feedback mechanism from the oropharyngeal structures may play some role in causing dysphagia. Patients who have had tracheostomy or prolonged endotracheal intubation often manifest swallowing dysfunction and continual laryngeal aspiration.

Tracheostomy has an effect on the swallowing reflex, particularly on the pharyngeal stage of swallowing. The mechanisms of an abnormal swallow associated with tracheostomy are not entirely clear. However, several possible causes have been proposed. These include: (1) decreased laryngeal elevation due to fixation of the trachea to the anterior neck skin; (2) obstruction by the cuff that leads to esophageal obstruction, causing
Table 1. The Sites and Some Causes of Depression of the Swallowing Reflex

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<thead>
<tr>
<th>Sensory receptors in the pharynx and the larynx</th>
<th>Damage to mucosa</th>
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<tbody>
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<td>Application of local anesthetics</td>
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<td>Afferent nerves</td>
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<td>Nerve injury</td>
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<td>Nerve block with local anesthetics</td>
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<td>Central nervous system</td>
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<td>General anesthesia</td>
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<td>Sleep</td>
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<td>Neoplasms</td>
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<td>Degenerative disease</td>
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<td>Nerve injury</td>
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<td>Acute idiopathic polyneuropathy</td>
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<td>Acute porphyria</td>
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<td>Muscles</td>
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<td>Neuromuscular blocking drugs</td>
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<td>Neuromuscular disease</td>
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The impairment of reflex swallowing also may occur in the central nervous system, including the swallowing center. In agreement with the clinical observations that the swallowing reflex is blocked readily by anesthesia, it has been shown that, in the paralyzed, vagotomized cat, deepening anesthesia by the administration of nitrous oxide progressively depresses the swallowing reflex elicited by stimulation of the superior laryngeal nerve (SLN). Furthermore, detailed analysis of HN activity during the swallowing reflex revealed that stimulation of superior laryngeal nerve produced three different responses in the HN: (1) a large amplitude burst of HN, (2) various forms of phasic HN bursts, and (3) tonic HN discharges. Although the large amplitude bursts in the HN characteristically observed during the act of swallowing were most sensitive to increasing depths of anesthesia, once it was elicited, the pattern and the amplitude of HN activity were independent of the depth of anesthesia. This finding is in agreement with the observation of Doty and Bosma, who showed that administration of pentobarbital caused considerable alterations in respiratory pattern, but was without effect on the organization of reflex swallowing, indicating the consistency of the motor pattern of the swallowing reflex. Various forms of phasic discharges related to nonswallowing acts were relatively resistant to increasing depths of anesthesia, but deepening anesthesia progressively depressed these discharges. Tonic discharges elicited by superior laryngeal nerve stimulation were the most resistant to increasing depths of anesthesia, although these discharges also seemed to be depressed by deepening anesthesia in a dose-related manner. The different sensitivity to anesthesia of these responses may suggest that the neural pathway relevant to each response has a different sensitivity to the depressant effect of anesthesia. Evans et al. have demonstrated a comparable depression of the esophageal motility during deepening anesthesia in humans; the central control mechanism for esophageal motility lies in the brain stem.

Disturbances in the swallowing reflex following surgical operations on the head and neck stem from resection of critical structures involved in the swallowing process or from sacrifice of afferent and/or efferent neural pathways. For instance, a delay in the swallowing reflex may occur secondary to resection of the faucial pillars, where the swallowing reflex is normally initiated. Surgical damage to glossopharyngeal nerve will cause significantly more problems in initiation the swallowing reflex. Similarly, decreased tongue movement secondary to local reconstructive techniques impairs the act of swallowing. Dysfunction of the hypoglossal nerve (HN) accentuates this problem.

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conceivable that such accidental inhalation of radio-opaque or radioactive materials might occur in part because of depression of swallowing reflex.

Even when the pharyngeal swallow is triggered normally, damage of neurologic or structural origin may be present to any one or more of the neuromuscular events that constitute it. Reduced soft palate closure, reduction in pharyngeal peristalsis, and reduced laryngeal closure all will result in insufficient swallowing and can cause the patient to aspirate on the inhalation following the swallow.

The swallowing reflex can be depressed without an apparent neurologic disorder. Our recent study showed that the swallowing reflex is greatly depressed by nasal continuous positive airway pressure (CPAP) in normal, awake subjects.75 Figure 5 shows the effects of increasing levels of CPAP on the swallowing reflex. With increasing levels of CPAP, number of swallows elicited by injection of water into the pharynx decreases and the latency of response is prolonged. Although the mechanism of this depression of the swallowing reflex is not clear, this effect may have important clinical implications because nasal CPAP is frequently used in various clinical situations.

**Clinical Syndromes**

Difficulty in swallowing, or dysphagia, is the clinical expression of disruption of the synchronized activity surrounding the normal swallowing mechanisms. Dysphagia may occur when a neurologic or structural disorder interferes with the smooth and efficient movement of materials from the mouth to the stomach or may result when there is reflux of materials from the stomach into the esophagus and sometimes up to the pharynx. The latter type of dysphagia may occur without the impairment of normal reflex swallowing. The

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*Fig. 4. Effects of inhalation of 50% N₂O on the swallowing reflex in a human subject. Experimental records show changes in submental electromyographic (EMG) activity during the swallowing reflex. The swallowing reflex was induced by injection of incremental volumes of water into the pharynx (arrows) and was identified by a submental EMG. During inhalation of 50% N₂O, the latency for initiation of the swallowing reflex was longer and the number of swallows was less than those during inhalation of 100% O₂, indicating that 50% N₂O depresses the swallowing reflex.*

*Fig. 5. Effects of nasal continuous positive airway pressure on the swallowing reflex in a human subject. Injection of water (0.5 ml) into the pharynx was performed (arrows), and the swallowing reflex was identified by a submental electromyogram (EMG). Increases in end-expiratory airway pressure progressively inhibited the swallowing reflex elicited by injection of water into the pharynx. Vₜ = tidal volume; Pₚₐ = airway pressure; EMG = submental EMG.*
following are specific neurologic disorders that can be associated with impaired reflex swallowing.

**Muscle Disorders.** The myopathies are disorders of muscle characterized by weakness. When the muscles of swallowing are involved, the impairment of reflex swallowing is apparent and there is risk for aspiration.

Polymyositis is an acquired myopathy characterized by acute or subacute muscle pain, tenderness, and symmetric weakness of proximal limb and trunk muscles without dermatitis or with minimal skin lesions. The onset is usually insidious, and the course is slowly progressive over several weeks or months. In one series of patients with confirmed pathology, dysphagia was noted in 21 of 40 patients. Furthermore, dysphagia was severe in 13 of 21 who had clinical evidence of overt aspiration, with respiratory complications in association with abnormal barium esophagram.

Progressive muscular dystrophy is characterized by inherited, progressive weakness with variable age at onset, distribution, and disability. In adult-onset cases, there is usually evidence of myotonia with facial, oropharyngeal, and limb weakness. Severe dysphagia occurs late in the disease. Patients with oculopharyngeal muscular dystrophy have incapacitating swallowing difficulties and aspiration with advancing age. In patients with muscle disorders, the use of central depressants, such as anesthetics or sedatives, may further suppress an already weak and atrophic musculature.

**Neuromuscular Junction.** Myasthenia gravis is an autoimmune disorder of the neuromuscular junction characterized by marked weakness and fatigability of muscles. Although almost any muscle in the body may be affected, the disease shows a special affinity for muscles innervated by the bulbar nuclei (face, lips, eyes, tongue, throat, and neck). Sudden inability to swallow or to breathe may occur at any time. Severe oropharyngeal weakness and ineffective cough predisposes the patient to aspiration; overt aspiration occurs with myasthenic crisis, defined as a temporary exacerbation requiring intubation and assisted ventilation. It has been reported that 25% of myasthenic crisis episodes were associated with radiographic evidence of aspiration pneumonia; 53% of the patients in crisis had severe oropharyngeal weakness and were at risk for aspiration.

Eaton-Lambert (myasthenic) syndrome is a neuromuscular disorder typified by presynaptic blockade. Although weakness in patients with this syndrome is usually in pelvic, thigh, and shoulder-arm muscles and ocular and bulbar muscles are usually spared, severe cranial weakness may occur with possible risk of swallowing difficulty and aspiration. Partial paralysis is a common clinical situation encountered during induction of or recovery from general anesthesia. Although partial paralysis may be safe in terms of maintaining adequate ventilation, the ability to overcome upper airway obstruction and to clear secretions at occasionally impaired. The recent study of Pawlin et al. demonstrated that, despite adequate ventilation, function of upper airway muscles is greatly impaired during partial neuromuscular blockade in awake subjects. More recently, the effects of partial neuromuscular blockade on the swallowing reflex have been systematically studied by Isono et al. They showed that partial neuromuscular blockade does not affect the neural pathway of the swallowing reflex but that both the elevation of the larynx and propelling force during swallowing are greatly disturbed by the administration of a subparalyzing dose of nondepolarizing muscle relaxant, causing disordered swallowing.

**Peripheral Nerve.** Dysphagia and aspiration can occur with disorders that affect peripheral nerves, such as Guillain-Barre syndrome or acute porphyria, or injury or trauma to the laryngeal nerves. Guillain-Barre syndrome is an acute demyelinating disease of peripheral nerve that often follows a viral illness or immunization. Progressive weakness and areflexia evolve over 1-4 weeks in association with elevated cerebrospinal fluid protein, slowing of conduction velocities with prolonged distal latencies and conduction block, and low-grade nerve inflammation and demyelination-remyelination. Treatment of Guillain-Barre syndrome is mainly symptomatic, and most patients recover spontaneously, but the time course is unpredictable.

Aspiration due to palatal and vocal cord paralysis with severe generalized weakness can be the presenting sign in acute porphyria. Many factors can precipitate the acute phase of the disease, including ethanol ingestion, infection, fasting, menstruation, and pregnancy. Certain drugs such as barbiturates used during general anesthesia also can precipitate an acute attack, and a knowledge of these is essential for the selection of anesthetic technique. The swallowing sequence can be disturbed when the peripheral nerves innervating the pharynx and larynx are damaged. It is a common clinical observation that the act of swallowing is seriously impaired when bilateral trauma to the HNs occurs and the tongue moves poorly, when the pharyngoesophageal sphincter does not relax, or when the larynx fails to elevate. Also, traumatic and surgical lesions of the

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laryngeal nerves may occur, with resultant vocal cord paralysis, incomplete glottic closure, and aspiration.

**Central Nervous System.** A number of causes affect the gray or white matter of the cerebral cortex, the subcortical gray matter, or the spinal cord (table 1). Depending on the anatomic region involved, the central nervous system (CNS) disorders can be classified into three categories: (1) diffuse disorders, (2) pyramidal system disorders, and (3) extrapyramidal system disorders. The diffuse disorders of CNS often cause impairment of reflex swallowing with resulting aspiration. For example, stroke predisposes the patients to dysphagia and aspiration acutely after cerebral infarction, and in some patients, dysphagia continues on a more long-term basis.\(^2\)\(^3\) Overall mortality from pulmonary complication alone, including aspiration, accounted for 29% of deaths in one autopsy series: mean survival was 13.7 days when those complication ensued.\(^2\)\(^3\) Dysphagia and aspiration can ensue after large unilateral lesions in the lateral medulla, after bilateral pontomedullary infarctions, and in the lacunar state; aspiration can be clinically overt or silent. In one series of patients studied up to 3 months after brainstem or cortical infarction,\(^2\)\(^4\) one-third had overt aspiration. Another one-third had silent aspiration not suspected clinically but identified by barium esophagram and videofluoroscopy. In both groups, dysphagia, weak cough, and dysphonia were common findings compared with the other one-third, who showed no evidence of aspiration. Diffuse brain lesions, head trauma, and metabolic disorders can cause severe depression of consciousness and place the patients at risk for aspiration. Elevated intracranial pressure can occur in association with intracranial neoplasm, hematoma, abscess, massive cerebral infarction, or closed head trauma. There may be associated stupor or coma.

The pyramidal system disorders comprise a group of disorders characterized by progressive lower motor neurons signs, including weakness, wasting, and fasciculation, often with corticospinal tract signs. They include progressive spinal muscular atrophy, progressive bulbar palsy, and amyotrophic lateral sclerosis. Poliomyelitis is another related disorder but is usually acute and now relatively rare. Morphologic abnormalities common to all are confined to motor neurons and their axons. Prominent bulbar weakness predisposes the patient to aspiration and other pulmonary complications and is a definite contributing cause of death.\(^2\)\(^7\)

The extrapyramidal disorders can be divided into those associated with hyperkinetic movements or those associated with bradykinetic movements. These disorders typically spare the sensory system, so that the primary disorder is limited to motor coordination. The hyperkinetic disorders include myoclonus, chorea, tardive dyskinesia, and dystonia. The bradykinetic disorders include the various forms of parkinsonism. Parkinsonism is characterized by involuntary tremors, diminished motor power, and rigidity, while the mental faculties are not affected. There is a distinct neuropathology with depigmentation of the substantia nigra, decreased production of dopamine in nigrostriatal neurons, a progressive clinical course, and amelioration of symptoms when treated with levodopa preparations. Swallowing dysfunction and aspiration occur in association with bradykinesia and rigidity, although overt aspiration is uncommon in patients with parkinsonisms responsive to levodopa therapy.\(^8\)\(^8\)

**Miscellaneous.** In addition to the physiologic abnormalities in swallowing, a variety of anatomic disorders can occur in the oropharyngeal stages of the swallow, particularly in patients treated for head and neck cancer. For instance, if there is any scar tissue in the oropharyngeal region after surgery or radiotherapy, it may inhibit the normal muscle contraction of the area and thereby cause insufficient swallowing.

Swallowing abnormalities also may occur with some mucocutaneous disorders such as epidermolysis bullosa and pemphigus.\(^6\)\(^3\) These disorders often involve mucous membrane of the oropharynx and esophagus. Chronic scarring of the oral cavity can result in a narrow aperture and immobility of the tongue, and esophageal bullae may lead to strictures.

**Diagnostic Approach**

As is the case with clinical problems, a thorough history and physical examination are important to evaluate swallowing disorders. History helps distinguish oropharyngeal dysphagia from disorders of more distal area. A variety of techniques are available for visualization of the activity of the oropharynx during swallowing. Among these are fluoroscopy, scintigraphy, computed axial tomography, ultrasound, magnetic resonance imaging, endoscopy, electromyography, and manometry. Each technique has certain advantages as well as inherent limitations. Use of one technique will provide the diagnostician with only a partial assessment of the components of swallowing, and therefore a combination of two or more techniques is preferable. For example, manometry is best used when paired with videofluoroscopy, because radiographic imaging best

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records sphincteric opening, whereas manometry records only sphincteric closing. In normal subjects, the swallowing reflex can be elicited easily by bolus injection of a small amount of distilled water into the pharynx or by continuous infusion of water, whereas the swallowing act can be identified by submental electromyogram and/or pharyngeal manometry. This simple technique is noninvasive and has many uses in evaluating the swallowing reflex in various clinical situations.

Oropharyngeal dysphagia is expressed clinically as difficulty in initiating a swallow. However, this does not necessarily mean that the swallowing reflex is depressed. Oropharyngeal dysphagia may be due to local structural lesions such as pharyngeal abscesses, carcinoma, and webs of the proximal esophagus or to motility disorders such as cricopharyngeal achalasia and Zenker's diverticulum. In these disorders, the presence of normal manometric recording does not always rule out cricopharyngeal dysfunction.

In considering the causes of dysphagia, special care should be taken to investigate the esophagus, because various anatomic and physiologic abnormalities can produce severe dysphagia. Esophageal dysphagia may be due to obstructive lesions such as neoplasms, webs and rings, strictures, and extrinsic compression, or to motility disorders such as achalasia, symptomatic diffuse esophageal spasms, and scleroderma. In these patients, dysphagia occurs late in the swallow with the normal elicitation of the swallowing reflex. Many patients with an esophageal problem have some form of gastroesophageal reflux that may be the forerunner of pulmonary aspiration. Differential diagnosis of swallowing disorders has important anesthetic implications, particularly when dysphagia is a manifestation of a certain systemic disease. The initial recognition of the underlying disorder has management and therapeutic implications. For example, management of anesthesia for patients with myasthenic gravis should take into account preoperative drug therapy and the potential impact of this drug therapy on responses to muscle relaxants. Similarly, for patients with the diagnosis of acute intermittent porphyria the use of thiopental is contraindicated. Even in the absence of systemic diseases, the diagnosis is important. For example, esophageal intubation is especially hazardous in patients with Zenker's diverticulum.

Management of Swallowing Disorders

Treatment for the impairment of reflex swallowing, when available, is directed against underlying disorders or conditions. Although treatment of most of neurologic disorders is usually supportive, pharmacotherapy may ameliorate symptoms in some patients. For example, many myasthenic patients are controlled adequately with anticholinesterase drugs given orally in tablet form.

Some patients need a cuffed tracheostomy tube, tube feeding, and prolonged nursing care. However, tracheostomy may cause more aspiration than it prevents.

Cricopharyngeus muscle dysfunction associated with systemic disorders such as parkinsonism and myasthenic gravis may improve with medical treatment for the disorders. Also, cricopharyngeal spasm that results from gastroesophageal reflux may resolve with medical treatment of the reflux, such as alteration of diet and medications including histamine₂ blockers and metoclopramide. Improvement in cricopharyngeus muscle function also may occur spontaneously as in some patients recovering from cerebrovascular accidents. Although intensive swallowing therapy or bougienage sometimes can help improve cricopharyngeal function, the most effective treatment for persistent cricopharyngeus muscle dysfunction is cricopharyngeal myotomy. In fact, cricopharyngeal myotomy was used successfully to improve swallowing in a patient with bulbar poliomyelitis.

For those patients with intractable aspiration and in whom recovery is expected only after a prolonged period of time, surgical procedures such as surgical closure or diversion of the larynx often are required.

Anesthetic Considerations

Patients with swallowing disorders are at risk, particularly during the perioperative period. Therefore, the anesthesiologist should focus on the preoperative preparation, the intraoperative plan for the use of drugs, and the postoperative care plan.

Patients with dysphagia often are severely dehydrated and malnourished with the signs and symptoms of a starving patients. These conditions should be corrected before elective surgery.

Patients suspected of having chronic aspiration should be checked carefully for the presence of pneu-
monia. If found, surgery should be delayed until proper preoperative evaluation and preparation are made.

In the presence of chronic aspiration, serious consideration must be given to nonoral feeding procedure such as nasogastric or gastrostomy tubes or parenteral alimentation to prevent aspiration and allow adequate fluid and caloric intake. Nasogastric tube feedings usually are not satisfactory methods for chronic nutritional support of patients with severe swallowing disorders because nasogastric tubes may make both upper and lower esophageal sphincters incompetent. A feeding gastrostomy is the procedure of choice for most patients.

Maintenance of sufficient oral hygiene is also important because aspiration of oropharyngeal secretions containing large numbers of bacteria may produce aspiration-associated pulmonary infections.

Some reports suggest that a 4-h fasting is unnecessary in elective surgical patients, particularly if a histamine$_2$-receptor antagonist is given at the same time. However, this recommendation should not be extended to patients with dysphagia. For example, prolonged retention of previously ingested foods occurs frequently in Zenker’s diverticulum and predisposes patients to regurgitation of undigested foods and occasional aspiration. It seems reasonable not to allow the patients to ingest any food or liquid at least for 4 h before anesthesia. In tracheotomized patients, secretions or food substances that pass through the larynx will be kept above the tracheostomy tube cuff so that careful suctioning of secretions above the cuff is necessary preoperatively.

Metoclopramide or domperidone could be used as part of preoperative medication, particularly in patients with known gastroesophageal reflux, to reduce the incidence of silent regurgitation during anesthesia. By contrast, anticholinergic drugs such as atropine and hyoscyine used as part of premedication could increase the incidence of silent regurgitation. Anticholinergic drugs, therefore, should be used with caution as premedicants and preferably combined with metoclopramide. Histamine$_2$ blockers also may be useful. In one study, the use of cimetidine in patients with heartburn and asthma not only decreased gastroesophageal reflux symptoms but also improved the pulmonary function parameters after 8 weeks.

The risk of aspiration associated with general anesthesia in patients with swallowing difficulties may be reduced by the use of a purely regional anesthetic technique. Should general anesthesia be selected, the choice of anesthetic agents and muscle relaxants is determined with consideration of underlying disorders or conditions. However, a rapid induction/intubation of the trachea sequence with simultaneous application of cricoid pressure to protect the patient’s airway seems to be mandatory.

Postanesthetic care is as important as preoperative care. The residual effects of anesthetics and muscle relaxants may aggravate the already obtunded upper airway reflexes. Furthermore, postoperative nausea and vomiting are common after general anesthesia, which may predispose the patients to aspirate in the absence of protective reflexes.

Conclusion

We know that the swallowing reflex plays an important role in prevention of aspiration and that impairment of reflex swallowing results from a defect or disorder in any part of the swallowing reflex arc. Central depressants such as sedatives and anesthetics also can depress the swallowing reflex. However, we still know remarkably little about the mechanisms of such depression, mainly because we do not have much information about the central neurochemical and/or neurophysiologic mechanisms controlling the swallowing reflex. In this context, an understanding of neurochemical processes in the central nervous system may be important in understanding pathophysiologic conditions such as dysphagia. For example, although a growing body of evidence suggests that a central dopaminergic mechanism may play an important role in controlling the swallowing reflex, we have little information about the effects on the swallowing reflex of certain drugs such as butyrophenones and phenothiazines that block dopamine receptors in the central nervous system. Theoretically, the swallowing activity may be attenuated in the presence of these drugs. However, this hypothesis is not yet substantiated.

Swallowing problems can be a manifestation of systemic disease or primary local lesions. In a dysphagic patient, various aspects of the anatomy or the neuro-muscular control may be damaged, causing slowed oral intake, obvious swallowing difficulty, malnutrition, coughing, and/or pulmonary complications. Detailed examination of the anatomy and physiology of swallowing is necessary to effectively treat the patients who aspirate because of a variety of anatomic or physiologic disorders.

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SWALLOWING REFLEX

Although management of anesthesia in patients with dysphagia is based on an understanding of the pathophysiology of this condition, all patients with dysphagia are predisposed to regurgitation and aspiration and, therefore, should be regarded as having a “full stomach.”

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