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palatoglossus (X), and paltopharyngeus muscles (innervation from pharyngeal plexus: X). This group of muscles is called the “leading complex.” The middle and inferior constrictor muscles then contract in an overlapping sequence. The oropharyngeal sequence ends when the wave of contraction reaches the upper esophageal sphincter. Electrophysiologic studies have shown that any background electrical activity in the swallowing muscles is inhibited with the onset of electrical activity in the leading complex and that inhibition is also found in the muscles of the leading complex just before they contract during swallowing (Doty, 1968; Doty & Bosma, 1956; Hrycyshyn & Basmajian, 1972; Miller, 1982; Moore & Dalley, 2002, 2006).

NEURAL CONTROL OF THE PHARYNGEAL PHASE OF SWALLOWING

The complex oropharyngeal muscle contraction and relaxation sequence that results in a successful swallow is triggered and controlled by a group of neurons within the reticular formation of the brainstem. These neurons are collectively referred to as a central pattern generator because they drive a sequence of complex but repetitive movements. The neurons of the central pattern generator directly stimulate several pools of motor neurons located in various brainstem cranial motor nuclei responsible for excitatory and inhibitory signals to the muscles of the oropharynx involved in swallowing. Peripheral feedback from sensory receptors in the muscles and mucosa of the pharynx is thought to modify the swallow sequence via direct input to the neurons of the central pattern generator. The central pattern generator can therefore be subdivided into three systems: an afferent input system from peripheral sensory mechanisms to the center, an efferent system corresponding to the motor outputs from the center to the muscles of the pharynx, and an organizing system corresponding to the interneuronal network within the brainstem that programs the motor pattern. Within the central pattern generator, some neurons may participate in activities other than swallowing such as respiration, mastication, and vocalization. Respiration is also likely controlled via a central pattern generator that coordinates with the swallowing pattern generator to integrate swallowing and respiratory functions (Altschuler, Bao, Bieger, Hopkins, & Miselis, 1989; Broussard, 2000; Doty & Bosma, 1956; Jean, 1990; Jean, Car, & Roman, 1975).

Afferent Input to the Central Pattern Generator

Branches from three cranial nerves: the trigeminal (V), the glossopharyngeal (IX), and the vagus (X) provide peripheral sensory feedback to the central pattern generator. The most sensitive oropharyngeal mucosal receptor regions for the stimulation of the swallowing sequence are innervated by fibers of the glossopharyngeal nerve via the pharyngeal plexus and by the superior laryngeal nerve (SLN) via the vagus nerve. Stimulation of the SLN induces pure swallowing with a short latency, and this finding has led to the belief that the fibers of the SLN constitute the

Both the glossopharyngeal and the SLN send fibers to the nucleus tractus solitarius (NTS) in the brainstem. The NTS is the principal sensory nucleus of the pharynx and esophagus and all the afferent fibers involved in initiating or facilitating swallowing converge in the NTS, mainly in the interstitial subdivision. Almost all of the NTS neurons that are involved in swallowing are activated with stimulation of the SLN. Most of the same NTS neurons can be activated by stimulation of the glossopharyngeal nerve. During swallowing, stimulation of sensory receptors in the pharynx by the posterior projection of the bolus is thought to initiate the involuntary pharyngeal phase of swallowing coordinated by the central pattern generator via the SLN (Altschuler, 2001; Jean, 2001).

Although the oropharyngeal swallowing motor sequence is centrally organized, it can change in response to peripheral afferent information. The same irreversible muscle sequence is exhibited during swallowing of food, liquids, or saliva but sensory information received from peripheral receptors can modulate the central network activity to adapt the swallowing motor sequence according to bolus consistency and size. Oropharyngeal muscle contraction timing, duration, and likely intensity, change with changes in bolus size and consistency. Sensory feedback likely modifies the central program, by adjusting the motor outputs depending on the contents of the oropharyngeal tract. In other words, continuous sensory feedback from the pharynx may influence the neurons of the central pattern generator and thus modulate the central program. Considerable variability in the sequence of events that occurs during the pharyngeal phase of swallowing can be appreciated on videofluoroscopic studies of swallowing in normal individuals. Ablation of sensory feedback does not, however, disrupt sequential discharge of the cranial motor nerve fibers that occur during swallowing (Hamdy et al., 1997, 1999; Jean, 2001; Kendall, 2002; Kendall, McKenzie, Leonard, Goncalves, & Walker, 2000; Kendall, Leonard, & McKenzie, 2003).

Higher Cortical Input to the Central Pattern Generator

Higher cortical input is also thought to influence the coordination of swallowing by the central pattern generator. Many of the neurological disorders that result in dysphagia do not involve the brainstem but rather affect a wide range of supramedullary central neural regions. In addition, the fact that swallowing can be initiated voluntarily without stimulation of the pharynx by a bolus, such as in a “dry” swallow, indicates that input from cerebral cortex can trigger swallowing.

The mechanism by which higher cortical centers impact swallowing function is poorly understood, but it appears that a widespread network of brain regions participate in the control of swallowing. It is hypothesized that
Figure 1-12. Brainstem motor nuclei. (Reprinted with permission from Moore & Dalley, 2006, Clinically Oriented Anatomy [5th ed., p. 1085]. Copyright 2006 Williams and Wilkins, Baltimore, Figure 8-23.)
postinhibitory rebounds, the inhibitory connections may be at least partly responsible for the progression of the contraction wave (Jean, 2001).

**Brainstem Interneurons**

**Responsible for the Programming and Coordination of the Swallowing Sequence**

The network of brainstem neurons thought to be responsible for the coordination of the pharyngeal swallowing motor sequence is called interneurons or premotor neurons. In general, central nervous system interneurons are identified by their connectivity with multiple areas of the brainstem and other areas of the central nervous system. Specifically, the physical connections of the central swallowing pattern generator interneurons provide an anatomic substrate for the integration of swallowing-related activities with airway-protective reflexes. The interneurons of the central swallowing pattern generator are thought to be located in two main brainstem areas, although some controversy exists regarding their exact locations. The dorsal swallowing group (DSG) of interneurons is located in the dorsal medulla within the NTS and adjacent reticular formation. The neurons of the NTS receive and integrate sensory information. The ventral swallowing group (VSG) of interneurons is located in the ventrolateral medulla just above the nucleus ambiguous. The motor nuclei of the nucleus ambiguous control the pharyngeal muscles (Amirali, Tsai, Weisz, Schrader, & Sanders, 2001; Chiao, Larson, Yajima, Ko, & Kahrlas, 1994; Ezure, Oku, & Tanaka, 1993; Gestreau et al., 2005; Kessler & Jean, 1985; Larson, Yajima, & Ko, 1994).

DSG interneurons are thought to be involved in triggering, shaping, and timing the sequential swallowing motor pattern. These interneurons exhibit a sequential firing pattern that parallels the sequential motor pattern typical of deglutition, with considerable overlap between the sequential firing of the various neurons. The neurons in this part of the reticular formation have been shown to have direct connections with the motor neurons that drive the musculature of the pharynx involved in swallowing. Each DSG neuron may be directly activated by signals from peripheral afferent fibers originating in the corresponding part of the oropharynx that is under its control.

Stimulation of the SLN results in initial activity, producing a single spike, in all of the DSG interneurons (see Figure 1–12). Some of the neurons in the DSG exhibit activity before the onset of the swallowing motor sequence, which is continuous and is called “preswallowing activity.” Those DSG interneurons that display preswallowing activity can be activated by stimulation of both the SLN and the glossopharyngeal nerve. This pattern of activity observed in the DSG interneurons suggests that these neurons are involved in the initiation of swallowing. Cortical input into the swallowing central pattern generator has been found to involve the neurons of the DSG. The DSG neurons, therefore, receive convergent information from both cortical and peripheral inputs that trigger swallowing. Finally, the two hemi-central pattern generators located in each half of the medulla are tightly synchronized...
and it is thought that this connection occurs within the DSG of interneurons (Cunningham & Sawchenko, 2000; Jean, 2001; Kessler & Jean, 1985).

The interneurons of the VSG are thought to be “switching” neurons that distribute and coordinate the swallowing drive to the various pools of motor neurons involved in swallowing. The firing behavior of these neurons also exhibits a sequential pattern, but with more overlap, longer latency, greater duration variability, and lower frequency than the interneurons of the DSG. This type of firing behavior indicates that the connections between the VSG interneurons and their afferent fibers are likely to be polysynaptic. The VSG interneurons are probably activated by the interneurons of the DSG. They, in turn, are connected to all the various groups of motor neurons involved in swallowing and, within the VSG interneurons, each neuron can project to more than one motor nucleus. The trigeminal and hypoglossal motor nuclei are connected only to the VSG interneurons and not to the DSG. Swallowing motor neurons only receive input from the ipsilateral efferent fibers of the ventral swallowing interneurons (Amri, Car, & Roman, 1990; Jean, 2001; Kessler & Jean, 1985; Larson et al., 1994).

In addition to the interneurons of the ventral and DSGs, swallowing interneurons have been identified within the trigeminal and hypoglossal motor nuclei, or in close proximity. They may play the role of premotor neurons or be involved in the organization of the swallowing drive to the various motor neurons involved in swallowing within a single motor nucleus. They might also be involved in the bilateral coordination of the motor neuron pools (Car & Amri, 1987; Jean, 2001; Kessler & Jean, 1985; Ono, Ishiwata, Kuroda, & Nakamura, 1998).

There is also a population of interneurons, identified more rostrally in the pons, that fire during the oropharyngeal phase of swallowing. These interneurons have been classified as sensory relay neurons and are thought to provide information from the oropharyngeal receptors to the higher nervous centers (Jean, Kessler, & Tell, 1994).

In conclusion, the DSG interneurons are involved in initiating the swallowing sequence. They stimulate the interneurons of the VSG which then modulate and coordinate the stimulation of the various motor neurons involved in the swallowing sequence (Bieger, 2001; Roda, Gestreau, & Biachi, 2002).

**ESOPHAGEAL PHASE**

The bolus is transported down the esophagus into the stomach. The esophageal phase is quite simple and consists of a peristaltic wave of contraction that propagates down the esophagus. There is considerable variability in the speed and strength of the esophageal peristaltic wave. Once initiated, it is not an all-or-none phenomenon, but may dissipate before reaching the lower esophageal sphincter. Sensory feedback likely plays a role in regulating the speed and intensity of the esophageal peristaltic wave, depending on the characteristics of the bolus. The lower esophageal sphincter is a site of high pressure, resulting from tonic contraction of the smooth muscle making
folds. Patients may complain that foods get stuck at various locations in the pharynx. It is important to determine where this sensation occurs as it can focus the physical examination on the areas most likely to be involved or abnormal. It is also important to determine if difficulty is experienced with solids only, or with both liquids and solids. Dysphagia for solids only is often caused by an obstruction or narrowing of the alimentary passage and a history of dysphagia for both liquids and solids may indicate generalized neuromuscular incoordination, or a very advanced obstructive process. Dysphagia for liquids only is often seen with a vocal fold paralysis or paresis because liquids tend to drip into the airway where a solid bolus holds together better and usually causes little difficulty. A history of weight loss underscores the severity of the problem and a history of pneumonia indicates the occurrence of intolerable aspiration. Meal duration may be prolonged in these patients and they may avoid certain types of food they know to worsen their symptoms (Castell & Donner, 1987).

A sudden onset of dysphagia is more likely to occur with trauma or ingestion of a foreign body. Careful questioning of the patient may be required to elicit a history of chicken or fish in the recent diet.

**Past Medical History**

A history of heartburn, indigestion, or known gastroesophageal reflux is significant in that chronic irritation of the pharyngeal mucosa can enhance a foreign-body sensation. A long exposure of the esophageal mucosa to stomach acid may lead to poor relaxation of the upper esophageal sphincter and subsequent solid-food dysphagia. Over time, failure of upper esophageal sphincter relaxation can lead to the development of pharyngeal diverticuli. Gastroesophageal reflux can also lead to aspiration of an extremely caustic nature that is not necessarily associated with swallowing (Leonard, & Kendall, 1999; Shaker, 1995).

A history of neuromuscular disease is important as this may be the primary etiology of the swallowing abnormality and give an indication of the prognosis for improvement. Past surgical procedures involving structures of the oral cavity and pharynx may be responsible for altered swallowing function. Head and neck radiation therapy can lead to fibrosis of structure whose mobility is required for adequate swallowing and will cause xerostomia (Kendall, McKenzie, Leonard, & Jones, 1998).

A detailed medication history may shed light on factors contributing to the patient’s symptoms of dysphagia. Many medications cause decreased salivary production and contribute to poor bolus lubrication and clearing. These medications act primarily through their effects on the parasympathetic nervous system, responsible for the stimulation of salivation. Drugs may be “parasympathomimetic” meaning that they stimulate or simulate the parasympathetic nervous system. This results in increased salivation, occasionally to the point of drooling. Drugs that are “parasympatholytic” block or decrease parasympathetic stimulation causing a decrease in salivary output and a dry mouth. “Anticholinergic” drugs fall into this category. Antihistamines and anti-nausea medications commonly have anticholinergic side effects. The use of
multiple drugs, a common finding in older patients, may result in drug interactions that potentiate the anticholinergic effects of those drugs. The side effect of a dry mouth can reduce the patient’s ability to communicate, predispose to malnutrition, promote mucosal damage, denture misfit, or dental caries, and increase the risk of serious respiratory infection secondary to the loss of antimicrobial activity of saliva (Feinberg, 1993; Narhi et al., 1992).

Other drug categories also have dry mouth as a side effect. The following discussion provides a partial list of examples of these drug categories. The side effects of any drug can usually be investigated by referencing any of a number of drug handbooks or the Physicians Desk Reference (Arky, 1996).

Drugs that increase brain dopamine levels by stimulating the release of dopamine may cause a dry mouth. An example of this type of medication is Symmetrel, a drug that is used in the treatment of Parkinson’s disease. Antipsychotic medications that act by blocking dopamine receptors also cause a dry mouth. Tricyclic antidepressants are basic in the treatment of depression. These drugs are thought to block serotonin and norepinephrine reuptake. They include Elavil, Senequan, and Tofranil. Some patients taking this type of medication experience dry mouth as these drugs produce a significant reduction in salivary flow. Newer antidepressants that block serotonin reuptake are also known to cause dry mouth. Examples of these medications include Prozac, Zoloft, Desyrel, and Paxil. Lithium carbonate used to treat manic-depressive disorders causes a dry mouth. Benzodiazepines are drugs used to treat symptoms of anxiety. The drugs act by potentiating the effect of GABA, a brain inhibitory neurotransmitter. Dry mouth is a side effect of many of these compounds (Hunter & Wilson, 1995; Vogel & Carter, 1995).

Diabetes mellitus is also associated with reduced salivary flow. In the case of diabetes, oral dryness is not associated with a malfunction of the parasympathetic nervous system but appears to be caused by disturbances in glycemic control (Sreebny, Yu, Green, & Valdini, 1992).

EXAMINATION

The patient should be sitting upright for the examination. A bright light source is required to illuminate the oral cavity, pharynx, and hypopharynx. A head mirror or headlight is recommended. The patient should be seated at a level so that he or she is slightly higher than the examiner. The legs should be uncrossed and the patient should be sitting up straight, leaning slightly forward at the hip.

The face of the patient should be examined for any obvious asymmetries or outward signs of trauma. Facial musculature and sensation should be tested to rule out abnormalities of cranial nerves V and VII. The eyes and orbits should be evaluated for deficits of cranial nerves II, III, IV, or VI. Abnormalities of cranial nerve function and facial sensation may be clues to the diagnosis of central or neuromuscular disease. A nasal exam should rule out any masses that could impinge upon the soft palate and therefore preclude complete closure of the velum.

The lips should be first inspected and evaluated in terms of sensation
Successful swallowing depends on the smooth and coordinated functioning of multiple structures in the head and neck region. Although the swallowing sequence can be influenced by input from higher cortical centers, it is primarily a semiautomatic mechanism. The swallowing mechanism relies on sensory input from the muscles and mucosal surfaces of the structures involved to help regulate and fine tune the sequence of muscular contractions that results in a swallow. It makes sense that disruption of the sensory, muscular, or structural integrity of the oral cavity, pharynx, and larynx may result in dysphagia. Any surgical procedure involving the head and neck region, therefore, has the potential to cause dysphagia. The discussion in this chapter focuses on the difficulty experienced by patients after surgery for head and neck cancer. These patients are the most common head and neck population to experience dysphagia, and the concepts involved in understanding the etiology of dysphagia in this group can be generalized to other patient populations.

During the last several years, greater emphasis has been placed on improving functional outcomes for head and neck cancer patients. This trend has been highlighted by the development of several “quality of life” measurement tools (Hammerlid et al., 1997; Hassan & Weymuller, 1993; Terrell, 1999). Patients have indicated through the use of these tools that their lives are most impacted by poor swallowing function and the presence of a stoma (Terrell, 1999). The development of “organ sparing” protocols employing combined chemo- and radiation therapy as a primary treatment modality for head and neck cancer is a step toward providing treated patients with improved speech and swallowing and freedom from a stoma (Eisbruch et al., 1999; Urba et al., 2000; Wolf et al., 1999).
Yet, despite increasing use of organ-sparing protocols, surgical therapy followed by radiation remains a primary treatment modality for head and neck cancer and is used as a salvage modality for patients who fail organ-sparing treatments. In keeping with the goal of improved functional outcomes, surgeons need to continue to focus their efforts on improved reconstruction techniques that maximally restore function.

The development of improved reconstructive techniques depends on a clear understanding of what is required for normal functioning and how it is disrupted by surgical extirpation of a tumor. This is particularly true for deglutition, a complex function involving modulation through sensory input, development of adequate pulsive forces, and competency of multiple valves. The advent of several techniques for the objective evaluation of deglutition, such as videofluoroscopy, has allowed for the in-depth analysis of normal deglutition and can be applied to the study of patients after head and neck cancer resection (Baker, Fraser, & Baker, 1991; Kendall, McKenzie, & Leonard, 2000; McConnel & O’Connor, 1994; Stachler et al., 1994). These techniques afford the ability to identify crucial functional elements lacking in specific patients or groups of patients. In particular, videofluoroscopy can provide information about the timing of bolus transit and swallowing gestures and the extent of structural displacements. In addition, multiple published studies provide normative data for comparison purposes and interobserver reliability for measurements made with this technique is typically greater than 90% (Kendall, McKenzie, Leonard, Goncalves, & Walker, 2000; Leonard, Kendall, McKenzie, Goncalves, & Walker, 2000). Many of the studies cited in this chapter involve the use of videofluoroscopy for patient evaluation.

Despite the availability of quantitative assessment techniques, investigations of swallowing function in cancer patients that have focused on the objective evaluation of specific alterations in swallowing and/or causes of dysphagia, and not just the presence or absence of aspiration, are relatively few. Reasons for this include the difficulty in grouping patients because of variability in tumor size and location and the involvement of other structures. However, it may be possible to identify general trends in swallowing function measured with videofluoroscopy based on the anatomical structures removed at the time of surgery and to develop reconstructive principles accordingly while tailoring the reconstructive design to each individual patient.

**INTRODUCTION**

In patients with head and neck cancer, interference with normal swallowing can result from the growth of the tumor that invades structures and impairs their functioning, or from the obstructive effects of the tumor, itself. Surgery to excise the tumor with a margin of normal tissue results in a defect and loss of structures, which typically also produces dysphagia. The chosen method of reconstruction of the defect will subsequently influence the character and the severity of the dysphagia. When radiation therapy is added to the regimen postoperatively, dysphagia...
the worse. Of necessity, these issues must be considered in any discussion of swallowing problems in neurogenic patients, and are a major focus of this chapter.

**CENTRAL NERVOUS SYSTEM DISORDERS**

**Stroke**

Dysphagia is seen in unilateral cortical lesions on either the right or left side, subcortical lesions, and brainstem lesions. Tongue motor function is rarely affected in cortical strokes because the nucleus of cranial nerve XII is in the median medulla and is not often impaired by vascular lesions. Problems are generally apparent in the pharyngeal component of swallow. The oropharyngeal (or mesopharyngeal) component (described as beginning at the juncture between the hard and soft palates and extending to the valleculae) is primarily involved, although the hypopharyngeal component (from the valleculae to the upper esophageal sphincter) may also be compromised (Donner, Bosma, & Robertson, 1985). Problems may relate to poor sensation, poor pharyngeal peristalsis, or discoordination or delay in the timing of bolus propulsion through the pharynx. Predicting those acute stroke patients likely to develop dysphagia from clinical signs alone is difficult (Mann & Hankey, 2001). In one report, more than half of patients with medullary strokes presented with clinical indications of dysphagia. Aspiration pneumonia appeared as an early complication in these patients, and dietary modifications did not prevent aspiration pneumonia. (Teasdale, Foley, Fisher, & Finestone, 2002).

Swallowing problems in stroke have been the subject of numerous dysphagia studies. However, until the past few years, the information available for dysphagia after stroke has been primarily qualitative. More recently, quantitative studies have provided additional useful information (Johnson, Mckenzie, Rosenquist, Sievers, & Lieberman, 1992). With clinical or bedside evaluation alone, aspiration is missed in approximately one half of patients with neurological or neuromuscular disease (Splaingard, Hutchins, Sultan, & Chaudhuri, 1988). Thus, the need for more definitive assessment, including videofluoroscopy, is clear.

Significant differences exist between the swallow-respiration patterns of patients with poststroke dysphagia and healthy volunteers. However, there is no evidence linking poststroke swallow-respiration characteristics with aspiration on simultaneous videofluoroscopy (Leslie, Drinnen, Ford, & Wilson, 2002). Because recovery from stroke is a time-related process, the timing of specific evaluation procedures is also important. In general, there is a need for early speech pathology assessment within the first week in order to evaluate the patient’s ability to handle oral intake and to provide a baseline for consistent follow-up assessment. Speech pathology and nursing personnel are then prepared to watch for evidence of aspiration, assess the need for more definitive diagnostic studies, and provide for a rational progression of dietary intake. Clinical factors that suggest the need for evaluation with a dynamic swallow study include: (a) aspiration pneumo-
nia, (b) cough and “wet lung” following swallowing, and (c) inability to maintain oral hydration and nutrition.

The dynamic swallow study is of value in identifying the presence of aspiration and the effects of various remedial strategies, even with no quantitative assessment. Our experience, however, suggests that the extra time and expense associated with obtaining objective measures can contribute significantly to patient care. As an example, our research has demonstrated that a kinematic pharyngeal transit time of more than 5 seconds (normal 1.00 ± .15 sec) is highly associated with aspiration pneumonia risk in stroke patients, whereas a time of less than 2 seconds has a low association (Johnson & McKenzie, 1993a).

There is only a rare indication for a dynamic swallow study in stroke before 2 weeks after onset. During this time, the patient stabilizes and time is allowed for recovery. This waiting period is particularly important in individuals with cerebral hemorrhage because excessive diagnostic study before 1 week may increase the risk for additional bleeding. Careful monitoring of patients during this time period will help determine the patient’s need and readiness for comprehensive evaluation. Well-timed and appropriate dynamic swallow studies will then prove to be valuable tools for management of dysphagia in stroke.

**Brain Injury**

Problems with swallowing and nutrition are significant difficulties in the management of individuals with traumatic brain injuries, in postoperative individuals after resection of brain tumors, and in patients with brain injury from hypoxia, encephalitis, or meningitis (Field & Weiss, 1989; Lazarus & Logemann, 1987). The evaluation techniques are the same as for individuals with stroke. Clinical factors such as aspiration pneumonia, cough or “wet lung” following feeding, or inability to maintain oral hydration and nutrition should trigger consideration for a dynamic swallow study. As with stroke, no individual with brain injury should have a dynamic swallow study if the sensorium is not clear enough to permit following instructions for the study or if trunk balance does not permit sitting upright in a chair. The time of day the study is done should include consideration of any diurnal variation in cognitive alertness. Irradiation exposure is, of course, significantly and directly related to the length of the procedure, which can be prolonged in these patients. Total exposure time of less than 5 minutes is preferred with a mean exposure time goal for all patients of 3 minutes.

In head injury, the most common problems identified with a dynamic swallow study are prolonged oral transit and delayed swallowing initiation. Aspiration is common. Pharyngeal peristalsis is reduced. Vallecular and piriform residue are prominent features of the dynamic swallow study (Leslie et al., 2002).

**Cerebral Palsy**

Cerebral palsy produces significant nutrition and swallowing problems for patients and their families (Field &
EPIDEMIOLOGY OF REFLUX

The incidence of laryngopharyngeal reflux is not clearly understood, but it has been estimated that up to 4% to 10% of patients with otolaryngologic complaints have underlying LPR (Toohill, Mustagh, & Lehman, 1990). In a community cohort of 100 patients without any history of voice or laryngeal complaints, 35% had symptoms of LPR and 64% demonstrated one or more physical finding of LPR on laryngoscopic examination (Reulbach, Belafsky, Blalock, Koufman, & Postma, 2001). This study suggested that physical findings and symptoms of LPR frequently are found in the general population and that some degree of LPR may be normal. In a prospective cohort of 113 new patients with laryngeal and voice disorders, 50% were found to have abnormal results on 24-hour dual pH probe testing (Koufman, Amin, & Panetti, 2000, 2001). LPR was highest in patients presenting with laryngeal neoplasia (88%) and muscle tension dysphonia (70%).

Reflux to a certain degree is ubiquitous in adults, and clinical disease only occurs in the presence of excessive reflux and/or a breakdown of mucosal defenses. In the lower esophagus, up to 50 reflux episodes at or below pH 4 in a 24-hour period is considered normal (Demeester, Johnson, Joseph, Toscano, & Hall, et al., 1976). In the pharynx, the normal or physiologic limit of reflux is not as clear. Generally, up to two episodes of reflux with pH less than 4 may be seen in healthy controls without LPR disease (Merati, Lim, Ulualp, & Toohill, 2005; Vincent, Garrett, Radionoff, Reussner, & Stasney, 2000; Ylitalo, Lindestad, & Ramel, 2001; Ylitalo & Ramel, 2002a, 2002b). However, animal studies have suggested that as few as three pharyngeal reflux episodes per week are sufficient to produce laryngeal reflux damage in the face of a pre-existing mucosal injury (Koufman, 1991).

DIFFERENCE BETWEEN LPR AND GERD

Laryngopharyngeal reflux must be distinguished from classic gastroesophageal reflux disease (GERD). The primary characteristics of GERD include heartburn and esophagitis. The majority of patients with LPR deny heartburn (70%), (Koufman, Aviv, et al., 2002) and the incidence of esophagitis only is about 25% in the LPR population (Koufman, 1991; Koufman et al., 2002; Koufman, Sataloff, & Toohill, 1996; Koufman, Belafsky, et al., 2002; Wiener et al., 1989). GERD patients tend to have primarily nighttime supine reflux, whereas LPR patients tend to have daytime upright reflux. Episodes of pathologic esophageal reflux may be prolonged, but LPR episodes are typically brief. Patients with GERD are more frequently obese, whereas body mass index is not related to LPR prevalence (Halum, Postma, Johnston, Belafsky, & Koufman, 2005). GERD is thought to be a result of lower esophageal sphincter dysfunction and/or esophageal dysmotility, but this does not appear to be true for LPR. Esophageal acid clearance is better in LPR patients than in classic GERD patients, (Postma, Tomek, Belafsky, & Koufman, 2001a) and LPR may be related to dysfunction of the upper esophageal sphincter (Celik, Alkan, & Ercan, 2005; Gerhardt, Shuck, Bor-
In the healthy adult, the esophagus is well-equipped to handle intermittent exposure to acidic gastric contents (Koufman, 1991). Lower esophageal sphincter competence is physically supported by: the muscular diaphragm; the acute angle of entry of the esophagus into the stomach (i.e., the cardiac angle); and the high abdominal pressure imposed on the intra-abdominal segment of the esophagus. LES pressure is also regulated by hormonal mechanisms and in response to alkalinization of gastric contents.

Primary peristalsis clears the majority of a distal esophageal bolus, and secondary peristalsis as a result of repeat swallows every 30 to 60 seconds allows for improved clearance as well as buffering by saliva. Salivary bicarbonate bathing the esophagus helps to neutralize refluxate within the esophageal lumen. Increased acid in the distal esophagus stimulates an increase in salivary production in the normal individual (Koufman, 1991).

The esophageal lining displays innate tissue resistance to physiologic reflux events. Mucus lining the esophageal lumen prevents the penetration of large molecules such as pepsin. The “unstirred water layer” below is rich in bicarbonate and buffers the environment adjacent to the esophageal mucosal cells. Furthermore, the esophageal epithelium itself is capable of blocking both acid and pepsin with cell membranes and intracellular bridges. Local blood flow is increased in the event of esophageal injury to facilitate recovery (Orlando, 1986).

In stark contrast, the larynx is poorly protected from injury by gastric refluxate, specifically acid and pepsin (Axford, Sharp, Ross, Pearson, & Dettmar, 2001; Johnston et al., 2003; Koufman, 1991). The upper airways are exquisitely sensitive to acid and especially to activated pepsin. Pepsin has been shown to be active above pH 4, suggesting that a smaller drop in pH is required to cause laryngeal injury than esophageal injury (Johnston, Knight, Dettmar, Lively, & Koufman, 2004). As noted above, very few episodes of pharyngeal reflux (three per week) can damage the larynx in the setting of a mucosal injury (Koufman, 1991; Little, Koufman, Kohut, & Marshall, 1985). The larynx is not protected by salivary bicarbonate, endogenous tissue buffering, or peristalsis. The larynx has poor intrinsic tissue defenses as well. Carbonic anhydrase isoenzyme III (CA III) is an enzyme with buffering capacity that is increased in the esophagus in response to acid. However, CA III is actually reduced in laryngeal tissue damaged by acid and pepsin, further decreasing laryngeal protection (Axford et al., 2001; Johnston et al., 2003, 2004).

**DIAGNOSIS OF LPR**

**Patient Symptoms**

The diagnosis of LPR is primarily based on a constellation of clinical signs and physical findings. In a 2002 survey sent to 415 members of the American Broncho-Esophagological Association, the responders were in agreement about certain symptoms of LPR (Book, Rhee, Toohill, & Smith,
These include throat clearing (98%), chronic cough (97%), globus (95%), dysphonia (95%), and postnasal drip (57%). The Reflux Symptom Index (RSI) has been shown to be a reliable and valid patient-administered questionnaire for identifying patient symptoms (Table 6–1) (Belafsky, Postma, & Koufman, 2002b). One group, however, has reported sensitivity and specificity for the RSI of 80.7% and 37.5%, respectively, in patients with hypopharyngeal reflux documented by pH studies (Park, Choi, Kwon, Yoon, & Kim, 2006).

The most common complaint of LPR patients appears to be dysphonia, followed by chronic throat clearing, cough, globus sensation, and dysphagia (Koufman, 1991; Woo, Noordzij, & Ross, 1996). Most LPR patients do not complain of heartburn. LPR has been implicated in the etiology of a multitude of otolaryngologic disorders, including subglottic stenosis, chronic sinusitis, chronic otitis media, laryngeal granulomas, paroxysmal laryngospasm, Reinke’s edema, Zenker’s diverticulum, and laryngeal carcinoma (Maronian, Azadeh, Waugh, & Hillel, 2001; Cohen, Bach, Postma, & Koufman, 2002; DelGaudio, 2005; Koufman, 1991; Lewin et al., 2003; Sasaki, Ross, & Hundal, 2003).

**Physical Findings**

Laryngeal examination with a flexible or rigid laryngoscope is essential to the diagnosis of LPR. Findings associ-

### Table 6–1. Reflux Symptom Index (maximum score 45)

<table>
<thead>
<tr>
<th>Within the past month, how did the following problems affect you?</th>
<th>0 = No problem</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hoarseness or a problem with your voice</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Clearing your throat</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Excess throat mucus or postnasal drip</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Difficulty swallowing food, liquids, or pills</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Coughing after you ate or after lying down</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Breathing difficulties or choking episodes</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Troublesome or annoying cough</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Sensations of something sticking in your throat or a lump in your throat</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Heartburn, chest pain, indigestion, or stomach acid coming up</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

**Total**

lated with LPR include erythema, laryngeal and vocal fold edema, subglottic edema/pseudosulcus vocalis, ventricular obliteration, posterior commissure hypertrophy, laryngeal granulomas, lymphoid hypertrophy, and excessive pharyngeal mucus. Endoscopic findings can be succinctly described with the Reflux Findings Score (RFS) (Table 6–2), which is an indicator of overall laryngeal inflammation.

It is important to recognize that the diagnosis is based on a constellation of findings rather than any one finding. For example isolated posterior commissure hypertrophy does not correlate well with LPR, but it is felt to be an important sign of LPR when associated

<table>
<thead>
<tr>
<th>Table 6–2. Reflux Findings Score (maximum score 26)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pseudosulcus (infraglottic edema)</strong></td>
</tr>
<tr>
<td>0 = Absent</td>
</tr>
<tr>
<td>2 = Present</td>
</tr>
<tr>
<td><strong>Ventricular obliteration</strong></td>
</tr>
<tr>
<td>0 = None</td>
</tr>
<tr>
<td>2 = Partial</td>
</tr>
<tr>
<td>4 = Complete</td>
</tr>
<tr>
<td><strong>Erythema/hyperemia</strong></td>
</tr>
<tr>
<td>0 = None</td>
</tr>
<tr>
<td>2 = Arytenoids only</td>
</tr>
<tr>
<td>4 = Diffuse</td>
</tr>
<tr>
<td><strong>Vocal fold edema</strong></td>
</tr>
<tr>
<td>0 = None</td>
</tr>
<tr>
<td>1 = Mild</td>
</tr>
<tr>
<td>2 = Moderate</td>
</tr>
<tr>
<td>3 = Severe</td>
</tr>
<tr>
<td>4 = Polypoid</td>
</tr>
<tr>
<td><strong>Diffuse laryngeal edema</strong></td>
</tr>
<tr>
<td>0 = None</td>
</tr>
<tr>
<td>1 = Mild</td>
</tr>
<tr>
<td>2 = Moderate</td>
</tr>
<tr>
<td>3 = Severe</td>
</tr>
<tr>
<td>4 = Obstructing</td>
</tr>
<tr>
<td><strong>Posterior commissure hypertrophy</strong></td>
</tr>
<tr>
<td>0 = None</td>
</tr>
<tr>
<td>1 = Mild</td>
</tr>
<tr>
<td>2 = Moderate</td>
</tr>
<tr>
<td>3 = Severe</td>
</tr>
<tr>
<td>4 = Obstructing</td>
</tr>
<tr>
<td><strong>Granuloma/granulation</strong></td>
</tr>
<tr>
<td>0 = Absent</td>
</tr>
<tr>
<td>2 = Present</td>
</tr>
<tr>
<td><strong>Thick endolaryngeal mucus</strong></td>
</tr>
<tr>
<td>0 = Absent</td>
</tr>
<tr>
<td>2 = Present</td>
</tr>
</tbody>
</table>

**Total**

Patients recovering from stroke, patients with dementia or other mental debilitation, elderly patients, and malnourished patients may fall into this category. All critically ill patients are at risk for dysphagia because of the general deconditioning and weakness of musculature involved in bolus propulsion and airway protection during deglutition. Poor oral care and the influences of intubation, changes in oral flora and bacterial overgrowth, and poor dentition lead to ventilator associated pneumonias (Munroe, 2004; Trieger, 2004). Deconditioned patients generally lack breath support and have a poor cough in response to airway penetration by food or liquid, making them less able to respond effectively to even mild aspiration. Evidence of repeated fevers or pneumonia in a patient should also stimulate concern if there is a possibility these symptoms could be related to aspiration.

**Pulmonary Risk Factors**

Patients with pre-existing pulmonary disease who become dysphagic have a diminished ability to tolerate even mild aspiration. Aspiration insults are very poorly tolerated by an already compromised pulmonary system. Pulmonary diseases include all the smoking-related lung diseases, for example, emphysema, chronic bronchitis, or lung cancer. Patients with cardiopulmonary pathologies such as cardiomyopathies, pulmonary hypertension, and cardiovascular diseases are also at heightened risk for pulmonary complications from dysphagia.

**Aspiration Pneumonia**

True aspiration pneumonia has a typical radiographic pattern. Aspirated materials are most often located in the right lower lobe, next most often in the right upper lobe, and less frequently in the left lower lobe. Rarely are all three lobes involved at once. This distribution is a consequence of the angle of the tracheobronchial tree into the parenchyma of the lung. The right lower lobe represents a straight line of descent from the trachea and right main stem bronchus. In a patient who is supine, or lying on the right side, the right upper

---

**Table 7-1. Risk Factors for Aspiration**

- Decreased level of consciousness.
- Supine position.
- Presence of a nasogastric tube.
- Tracheal intubation and mechanical ventilation.
- Bolus or intermittent feeding delivery methods.
- Malpositioned feeding tube.
- Vomiting.
- High-risk disease and injury conditions.
- Neurologic disorders.
- Major abdominal and thoracic trauma/surgery.
- Diabetes mellitus.
- Poor oral health.
- Inadequate R.N. staffing levels.
- Advanced age.

lobe takeoff from the right main stem bronchus represents a dependent position. The left lobe is in a dependent position in the left side lying position. The site of aspirated materials is thus influenced largely by gravity and human anatomy.

Symptoms of aspiration pneumonia in a patient must be thoroughly explored, both clinically and radiographically. To ensure appropriate treatment, pneumonia related to dysphagia, or to difficulty eating and drinking, must be differentiated from a pneumonia related to aspiration related to other etiologies. Aspiration pneumonia may be a result of material entering the lungs during a period of unconsciousness, such as can occur in trauma, diabetic coma, or acute myocardial infarction with loss of consciousness. Aspiration can also occur when patients who have been instructed to remain NPO (non per os, nothing by mouth) before surgery do not comply with the instructions. Under general anesthesia, or even conscious sedation, the patient is unable to protect the airway. Reflux occurs as the lower esophageal sphincter is relaxed and the patient aspirates. Similarly, individuals who have eaten a meal and then experience a traumatic event leading to unconsciousness are at very high risk for aspiration. This aspiration is preceded by vomiting or reflux, and may have devastating consequences for the pulmonary system (Metheny, 2002).

Repeated aspiration occurs when the airway is unable to maintain its normal hygiene. Long-term endotracheal intubation heightens a patient’s risk for repeated aspiration by the presence of an artificial tube that interferes with the normal cough, impairs the ciliary action of the lining of the trachea, and precludes the normal filtration and humidification of the nose and mouth. Even with cuffed endotracheal tubes and tracheostomy tubes, microaspiration into the tracheobronchial tree does occur. This is a consequence of the constant expansion and contraction of the trachea during normal respiration, and subsequent movement of the cuff in the airway.

Repeated aspiration may also be related to a patient’s inability to protect the airway during eating and drinking. For example, a larynx that is incompetent as a consequence of paralysis or radiation effects may not be able to close quickly or completely enough to prevent swallowed materials from aspiration. An insensitive larynx, caused by stroke, cranial nerve injury, or other factors, may precipitate aspiration of foods, liquids, or the patient’s own secretions. “Silent” aspiration can be particularly difficult to diagnose (Horner & Massey, 1988). In one study, only 42% (18/43) of a group of patients with documented aspiration on videofluoroscopy were identified as aspirating on bedside swallow evaluations (Splaingard, Hutchins, Sulton, & Chaudhuri, 1988). Patients who chronically aspirate may become undernourished and unable to maintain their weight. Immunological risk is heightened because of the lack of adequate protein, albumin, and fat stores to maintain normal function. Clinical findings include fever, shortness of breath, weakness, and coughing. Sputum may be thick, colored, and difficult to expel by coughing. Chest auscultation may reveal rhonchi in the large airways, and the person with true pneumonia may have characteristic egophony, or “E”
and oral symptoms and problems (Groher, 1984). Neurological problems could impact sensory and/or motor systems for swallowing, and should be recorded. Information from otolaryngological, or head and neck, exam, is crucial in understanding known problems of the oral, pharyngeal, and laryngeal anatomy. Report of mouth care and dental condition is important if available (Langmore et al., 1998; Loeb, Becker, Eady, & Walker-Dilks, 2003). If the vocal folds were observed during motion, their ability to adduct adequately will be important in determining adequate airway protection, as well as laryngeal sensation.

Any other medical problems, hospitalizations, and surgeries should be recorded, including dates of occurrence. Prior voice, speech, or swallowing problems, and intervention given, be it medical, surgical, or radiological, may impact swallowing and thus should be noted. Psychiatric and social history, including independence and availability of support, may impact the diagnostic and/or rehabilitative processes, and should be included, if relevant. A list of medications currently taken is important, as medications may cause xerostomia, drowsiness, or other symptoms relevant to swallowing. The clinician’s questions are guided by his or her knowledge of the complaint and history as he or she develops the differential diagnosis.

Feeding History

A. Method and Schedule of Feeding or Eating

The current method of nutritional intake is noted (i.e., oral with utensils or syringe, or nonoral feeding tubes, such as nasogastric, gastrostomy, duodenum, or jejunum tubes). Some of these methods may be used in combination, with one supplementing the other (see Chapter 10). Thus it is important to ask the patient or caregiver which feeding method is used at what time and with what substances.

B. Diet

Note the type, amount, and frequency of food and liquid intake, as well as preferences. Preferences for certain substances may tell you about the patient’s comfort level managing certain foods. Has the patient changed his or her eating habits because of the complaint? Does he or she seek out or avoid certain foods or liquids? Ask about changes over the course of a day. For instance, does the person eat more or less at one time of day than another?

C. Onset of Problem

The time and date of the onset of swallowing problems, and whether gradual or sudden, should be noted. Were problems concurrent with other medical problems, or did they occur following particular incidents?

D. Description of Problem

Whenever possible, the swallowing problem should be described in detail by the patient. During the interview, it can be important to focus the patient on their symptom descriptions, rather than the perceived diagnosis. Questions should attempt to elicit symptoms, current manifestations and the character of the swallowing problem.
1. **Context:** When do swallow problems occur? Do they occur at particular times of the day or during particular meals, and when during these meals (beginning, middle, end of meals, or after)? Are these meals at home, outside the home, with others, or when alone? (Are distractions such as talking during swallowing occurring?) Do the same or similar problems occur at other times besides eating?

2. **Cough or choke:** Do coughing and/or choking occur, and with what frequency and severity? Is the problem a tickle to which the patient responds or an uncontrollable cough? Has it interfered with breathing? Does it occur during or after swallowing, and/or at other times of the day, when meals are not being taken? Does the food “get stuck?” Ask the patient to point to “sticking” point. Does it eventually go down or need a liquid wash to clear? If the patient regurgitates or coughs, was it uncontrolled or was it done to relieve the sensation of food sticking? Has the patient needed the Heimlich maneuver to dislodge material from the airway?

3. **Weight loss:** Has the patient experienced recent weight change, and has this been because of a change in eating habits? Note the patient’s height and present weight compared to past weight.

4. **Localization and characterization:** Are there any other subjective descriptions of the problem? Can the patient point to the area in the mouth, throat, or chest where the problems seem to occur? Does the food “pocket” in certain areas? Is there any pain associated with swallowing? Have appetite changes been experienced? Does the patient experience dry mouth?

5. **Social or emotional impact:** How does the patient feel about the swallowing problem? Is it of concern? Have experiences with swallowing been frightening? Does the patient have a certain eating goal? A checklist may also be employed to record the patient’s subjective impression of the swallowing problem on his or her quality of life.

**E. Variability**

The variable characteristics of the problem should be described, such as:

1. **Foods:** Do problems occur with certain foods or food types? Note whether problems occur usually with liquids and/or solids, and the texture and consistency of those foods. This information may be used later in trial swallows. Are some foods easier to swallow than others? More difficult? Are liquids difficult to control? Do particular foods get “stuck”? Ask about dental care and problems chewing as this is often overlooked as an important factor with solids.

2. **Temperature:** Is the ease of swallowing affected by the temperature of the food? Are hot or cold foods easier or more difficult to swallow? This information may provide subtle clues or signs of a delayed swallowing response (i.e., if the patient finds cold foods easier to swallow, it may indicate a cold stimulus can facilitate swallow initiation).
reflexes and feeding skills evaluation, which is discussed next. Incorporating this aspect of the physical assessment with the evaluation of oral reflexes and feeding skills will diminish additional infant stress and crying associated with oral inspection.

4. Oral Sensory-Motor and Feeding Skills Assessment

The infant or child’s oral sensory-motor and feeding skills determine the types of foods safely handled. During the first 3 years of life, dramatic oral-motor and developmental feeding skill changes have profound effects on the types of food, textures, and feeding methods the infant or child can safely control. (See Table 9–2 for pediatric feeding skills development.)

The approach recommended for assessing oral sensory-motor and feeding skills is to progress from the least frightening or threatening (external touching of the face and mouth) to the most threatening (internal inspection of the mouth).

Some oral reflexes are common to all ages, but the most rapid oral reflex and feeding skill changes occur in infancy. Therefore, the oral reflexes and feeding skills assessments will be divided into three infant developmental stages covering the first year of life:

- Birth to 4 months
- 5 to 7 months
- 8 to 12 months

It is important to note that, although infants are referred to in this section, the clinician may find similar primitive reflexes still present in an older child with neurological deficits. Reflexes that are common to all age groups will be explained once, during the assessment of the oral reflexes and feeding skills of the infant from birth to 4 months.

**Birth to 4 Months**

Developmental feeding skills are affected by the infant’s gestational age. For example, preterm infants frequently demonstrate generalized hypotonia and immature development of their suck/swallow/breathing, thus affecting their feeding efficiency. However, somewhere around 33 to 34 weeks gestation, the healthy growing premature infant’s oral-motor maturation allows for suck/swallow/breathing coordination and the introduction of oral feedings (Casaer, Delieger, Decock, & Eggermont, 1982; Wolff, 1968). (See Table 9–2, Pediatric Feeding Skills Development; Preterm Infant.)

For term infants and premature infants whose postnatal age is corrected considering their prematurity the following reflexes and responses exist:

- Rooting reflex
- Suck reflex
- Bite reflex
- Gag reflex
- Tongue protrusion reflex
- Swallow reflex
- Lip and jaw closure
- Tongue mobility

When assessing these movements, start with the rooting reflex. Elicit the reflex by gently stroking the infant’s cheek. The infant will turn his or her head toward the touch with mouth open. The rooting reflex disappears between 3 and 5 months.
### Table 9-2. Pediatric Feeding Skills Development

<table>
<thead>
<tr>
<th>Age</th>
<th>Positional stability</th>
<th>Reflexes</th>
<th>Feeding skills</th>
<th>Types of food</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preterm infants</td>
<td>Lower tone</td>
<td>Gag reflex develops usually around 32 weeks gestation</td>
<td>Coordinated suck/swallow/breathing at 34-37 weeks Feeding readiness; gags with gavage tube insertion,</td>
<td>Breast milk or formula</td>
</tr>
<tr>
<td>(34–36 wks)</td>
<td>More extension</td>
<td>Suck reflex functionally mature at 32–34 weeks Rooting reflex elicited at</td>
<td>elicits oral and pharyngeal structural mobility support both respiration and feeding</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reduced buccal pads</td>
<td>32 weeks</td>
<td>Limited neck stability</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reduced cup shape of tongue</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Newborn to 3</td>
<td>Buccal pads present</td>
<td>Gag reflex</td>
<td>Rhythmic sucking pattern (average 1 suck burst/second for nutritive sucking, 2 sucks/sec for nonnutritive suck)</td>
<td>Breast milk or formula</td>
</tr>
<tr>
<td>months (full-term)</td>
<td>Lip closure</td>
<td>Rooting reflex</td>
<td>Oral-pharyngeal area is shared for feeding and breathing Hand to mouth activity Hand reaching toward bottle</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cup-shaped tongue facilitates transfer of liquid to pharynx</td>
<td>Tongue protrusion reflex</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Oral and pharyngeal structural mobility support both respiration and feeding</td>
<td>Suck/swallow reflex</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Limited neck stability</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4–6 months</td>
<td>Increasing stability of neck and shoulders</td>
<td>Transitional period—primitive reflexes are disappearing except for gag reflex</td>
<td>Beginning of up-and-down chewing (munching) Lateral tongue movement Lip closure around spoon begins Both hands to hold bottle Cup drinking introduced</td>
<td>Breast milk or formula</td>
</tr>
<tr>
<td></td>
<td>Lower lip positions around spoon</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tongue fills less space in oral cavity allowing for greater mobility and posterior</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>positional shift</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(continues)
degenerative disease who has been doing well for a long period of time may begin to fail. Or a patient recovering from surgery may leave the hospital doing well, but experience difficulty later in the postoperative period.

"Red Flags" for Formal Dietitian Consult

Significant changes in weight trends and hydration status in a patient signal the need for a comprehensive nutritional evaluation. Guidelines for determining the severity of unintentional weight loss are presented in Table 10–1.

In general, a person losing 10% to 20% of his or her usual weight may sustain moderate impairment, whereas a loss of greater than 20% of usual weight indicates severe impairment (Phinney, 1995). In both situations, thorough elaboration of the cause of weight loss will be required.

Red flags for suboptimal hydration include rapid weight loss (a 48-hour weight loss of 4 pounds can mean a negative fluid balance of 2 liters), complaint of thirst, skin turgor changes, decreased urination, a rising blood urea nitrogen level (BUN) in the absence of other renal indicators, and an increased serum sodium level (hypermantremia). Patients with thin liquid dysphagia may be at particular risk for alterations in hydration status. They will have difficulty augmenting fluid intake to compensate for increased fluid losses because of secondary illness and are also more vulnerable to other fluid-depleting conditions such as fever, diarrhea, or increased perspiration related to heat or physical exertion.

NUTRITIONAL ASSESSMENT

As noted, careful monitoring of patients’ nutritional status can and should be undertaken by members of the dysphagia team and other caregivers. However, expedient referral to the dietitian is indicated when there is any question regarding the patient’s ability to safely maintain adequate nutrition or hydration via the current means of food intake. Typically, another member of

<table>
<thead>
<tr>
<th>Time</th>
<th>Significant Weight Loss (%) of Change</th>
<th>Severe Weight Loss (%) of Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 week</td>
<td>1–2</td>
<td>&gt;2</td>
</tr>
<tr>
<td>1 month</td>
<td>5</td>
<td>&gt;5</td>
</tr>
<tr>
<td>3 months</td>
<td>7.5</td>
<td>&gt;7.5</td>
</tr>
<tr>
<td>6 months</td>
<td>10</td>
<td>&gt;10</td>
</tr>
</tbody>
</table>

Source. Reprinted with permission from Blackburn, Bistrian, Maini, Schlamm, & Smith Copyright © 1977, American Society of Parenteral and Enteral Nutrition.
the team has nutritionally screened
dysphagic patients and this has trig-
gerated a referral to the dietitian for a
more comprehensive assessment. Com-
ponents of the dietitian’s examination
include the following.

Anthropometric Data

As indicated, a primary cue for dietary
referral is weight change. Appropriate
weight range is impacted by gender,
age, height, and frame. The patient’s
usual weight, any change in this
amount, over what period of time, and
whether any change was intentional
must be determined (see Table 10–1). If
weight loss is too rapid, and in partic-
ular if it is associated with inadequate
protein intake, it may adversely impact
the body’s immune function. The ability
to resist disease and infection is com-
promised (Linn, Robinson, & Klimas,
1988). The patient’s energy level and
ability to participate in the prescribed
rehabilitation program may also be
affected. Presented in Table 10–2 are
guidelines for interpreting nutritional
status based on percent of ideal body
weight (IBW) and percent of usual
body weight (UBW).

Laboratory Data (Nutritional
Assessment, 1992; Krystofiak &
Mueller, 2007; Pesce-Hammond
& Wessel, 2005)

Visceral protein status is frequently
screened by obtaining a serum albumin
value (from a blood sample, usually
requested as part of a Comprehensive
Medical Panel). A value of less than 3.2
(Zeman, 1991, pp. 56, 77) to 3.5 (Nutri-
tion Screening Initiative, 1994, p. 19) is
suggestive of the patient being at nutri-
tional risk. Pre-albumin, can provide
a more sensitive indicator of current
protein status. However, pre-albumin,
a negative acute phase protein, may be
lowered in the presence of metabolic
stressors, inflammation, or infection, ir-
respective of nutritional state. Therefore,
a low pre-albumin value may not, in and
by itself, reflect compromised protein or
nutrition status. C-reactive protein (CRP),
a positive acute phase protein, can be
used as an indicator of stress or inflam-
mation (Pesce-Hammond & Wessel,
2005).

Table 10-2. Evaluation of Nutritional Status Based on a
Percentage of Weight

<table>
<thead>
<tr>
<th></th>
<th>% of Ideal Body Weight</th>
<th>% of Usual Body Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild malnutrition</td>
<td>80–90</td>
<td>85–95</td>
</tr>
<tr>
<td>Moderate malnutrition</td>
<td>70–79</td>
<td>75–84</td>
</tr>
<tr>
<td>Severe malnutrition</td>
<td>0–69</td>
<td>0–74</td>
</tr>
</tbody>
</table>

Source. Data from Rombeau, Caldwell, Forlaw, & Guenter (1989) p. 43.
Radiographic evaluation of the pharynx and esophagus is usually considered as two separate examinations that may be performed either separately or together for evaluation of a specific clinical problem (Logemann, 1983, 1986). Radiographic examination of the pharynx is typically referred to as a dynamic swallowing study, and is accomplished by videofluoroscopy, or video radiography. Other radiographic methods that can be used for examination of the pharynx include cineradiography and rapid sequence digital radiography. Recently, dynamic magnetic resonance imaging techniques (cine-MRI), which are noninvasive, have been described (Hartl, Kolb, Bretagne, Marandas, & Sigal, 2006; Kitano, Asada, Hayashi, Inoue, & Kitajima, 2002). However, technical limitations (i.e., poor temporal resolution, supine positioning) have, to date, limited their wide application. Radiographic examination of the esophagus is termed barium swallow or esophagram. This study is often combined with examination of the stomach and duodenum. To obtain optimal information from the examination and minimize radiation exposure, it is important to have an understanding of the indications and technique for each of these examinations.

DESCRIPTION OF EQUIPMENT

Examination of the pharynx and esophagus is generally done in a standard radiographic and fluoroscopic x-ray room that is equipped with some type of system for rapid sequence filming. The rapid sequence recording is necessary because the process of swallowing occurs quickly, and in order to analyze
the swallowing process, this capability must be available. During the early years of development of these examinations, cineradiography, which is essentially a recording of the amplified fluoroscopic image on film, was used for rapid sequence filming. The major advantage of this system was the high spatial resolution of the images and the ability to easily analyze individual frames; the major disadvantage was greater radiation exposure than with other methods, as well as difficulties related to processing and analysis of the film. Cineradiography is no longer available in most facilities and has been replaced by videofluoroscopy, which is a recording of the fluoroscopic image by a television monitor and magnetic tape or digital disk. Although spatial resolution is less than with cineradiography, it is generally adequate for most studies. It has the advantages of less radiation exposure, easier manipulation of the images, and the ability to record sound. More recently rapid sequence digital radiography which is capable of rapid sequence filming of up to six frames per second has become available. Advantages of this system include excellent spatial resolution, easy manipulation of the images, including brightness and contrast changes, and relatively low radiation exposures. The chief disadvantages are too few frames per second for some studies, and its lack of availability in many departments.

Exposure to radiation occurs with examination of both the pharynx and esophagus. For this reason, patients should be carefully evaluated before these studies are done to determine with certainty that the examination is indicated. This is of particular concern with younger patients. The referring physician, radiologist, and speech pathologist should all be involved in the decision. In addition, individuals conducting the examination should have knowledge of radiation exposure and use appropriate protection from radiation, for both the patient and the individuals conducting the examination. Radiation exposure to the patient can be measured in several ways, including skin exposure, gonadal dose, and total body exposure. Of additional concern in examination of the pharynx and upper esophagus is radiation exposure of the thyroid. Radiation exposure of the lens of the eye is also an important issue when the head and neck are exposed to radiation. A comparison of radiation exposure for the techniques used for radiographic swallowing studies is seen in Table 12-1. Factors affecting radiation dose include: kilovolt peak (kVp), which is the peak voltage across the x-ray tube; milliampere seconds (mAs), which is the tube current multiplied by exposure time; image field size; source to skin distance; source to detector distance; and use of a grid.

<table>
<thead>
<tr>
<th>Projection</th>
<th>Skin</th>
<th>Thyroid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posterior–anterior</td>
<td>9.5</td>
<td>.27</td>
</tr>
<tr>
<td>Lateral</td>
<td>7.7</td>
<td>.99</td>
</tr>
</tbody>
</table>

*Exposure factors include: Automatic brightness control with 65 kVp, 1.1 ma, 8:1 grid, source to skin distance, 46 cm; source to detector distance, 86 cm; 9’ field of view.
TRANSNASAL ESOPHAGOSCOPY

Distal chip videoscopes are now available that can provide high-resolution images of the esophagus through ultrathin transnasal endoscopes. Typical esophagoscopy is performed through the mouth with a rigid or flexible scope in a sedated individual. Transnasal esophagoscopy (TNE) may now be performed reliably and comfortably through the nose without sedation. We introduced TNE in 2000. Since that time we have reported our experience of over 700 cases (Postma et al., 2005). The most frequent indications for TNE...
were esophageal screening in persons with reflux, globus, and dysphagia. Only 17 procedures had to be aborted because of a tight nasal vault. The most serious complication has been self-limited epistaxis (<2%). In our practice, TNE has replaced radiographic imaging of the esophagus in patients with reflux, globus, and dysphagia. It has greatly enhanced our ability to diagnose esophageal pathology in persons with dysphagia. The most common findings encountered on TNE in persons with dysphagia are peptic esophagitis, hiatal hernia, Schatzki’s ring, Candida esophagitis, Barrett’s metaplasia, and carcinoma. Patients are not very accurate at localizing the site of their swallowing problem. Approximately one third of individuals who localize the site of their dysphagia above the clavicle will have an esophageal etiology to their symptom. Therefore evaluation of the esophagus is a critical component of a comprehensive dysphagia evaluation.

GUIDED OBSERVATION OF SWALLOWING IN THE ESOPHAGUS

The fiberoptic endoscopic evaluation of swallowing (FEES) is a tool to endoscopically evaluate the oropharyngeal phase of deglutition. Because TNE is performed in an unsedated, upright individual, we now have the ability to endoscopically evaluate the esophageal phase of swallowing. The guided observation of swallowing in the esophagus (GOOSE) is the esophageal counterpart to the FEES (see videoclip of GOOSE in materials folder for Chapter 5. In the clip, patient is given applesauce and its passage through the esophagus is observed. In the last portion of the clip, the scope is inserted through the lower esophageal sphincter and retroverted to watch a pill exit the esophagus into the stomach). The ultrathin endoscope is passed through the nose and placed at the level of the soft palate approximately 3 cm above the tip of the epiglottis. FEES is performed as per a previously established protocol (see Chapter 11). If an obvious source of the patient’s swallowing problem is encountered during the FEES, the GOOSE may be deferred. If the FEES is normal and no oral or pharyngeal disorder responsible for the patient’s dysphagia is encountered, or a comorbid esophageal disorder is suspected, the endoscope is passed through the upper esophageal sphincter into the cervical esophagus. Normal esophageal transit time is less than 13 seconds. Any residue from the previously performed FEES in the esophagus suggests delayed esophageal transit. With the scope in the esophagus the patient is first given a 15-cc bolus of thin liquid impregnated with blue or green food coloring. Esophageal peristalsis is visualized as the liquid passes. The lumen of the esophagus should obliterate around the endoscope as the liquid is transported through. The esophagoscope is promptly advanced to follow the food bolus as it moves through the entire length of the esophagus. The bolus is visualized until it passes into the stomach. If the liquid traverses the esophagus without difficulty the person is fed a puree (applesauce) and then a solid (marshmallow, cracker, or bagel) consistency. If the patient has a
wait. When a stable baseline or hold position is established, the patient is instructed to “swallow all at once.” If a stable hold position is not achieved the patient can be re instructed or support strategies to achieve a stable position can be introduced.

As long as swallow performance is adequate on a given bolus, the exam proceeds to the next step in the protocol. Instructions are repeated each time a bolus is offered. Otherwise, feedback, except for general encouragement (e.g., “you’re doing great,” “do your best”) should be avoided because it can change behavior. Similarly, the monitor should be positioned out of the patient’s field of view unless instruction regarding feedback is intended. If the swallow is not successful because of biomechanical failure but does not threaten airway safety for the next bolus step, then the protocol should proceed without changes in instruction.

■ Instructions for liquid, pudding, and paste boluses from spoon or cup: “Put this in your mouth, hold it in your mouth (or the front of your mouth) and, when I tell you to, swallow it all at once.”

■ Instructions for solid boluses: “Chew this and swallow when you are ready.”

■ Instructions for straw-drinking: “Put the straw in your mouth and, when I tell you, drink this as fast as you can.”

Oral, pharyngeal, or laryngeal failure that results in aspiration during the DSS justifies systematic alteration of the protocol. Compensations to avoid aspiration can be instructed so that the swallow can be evaluated as completely as possible. Because all compensations change swallow biomechanics, they must be taken into account during interpretation of objective and subjective observations.

DIAGNOSTIC AND THERAPEUTIC PROBES

Replicate the Symptoms

All DSSs begin with the standard protocol, which is followed as far as the patient can tolerate. Whether or not the standard protocol appears to reveal biomechanical failure, an attempt may be made to replicate the complaint. For example, if dysphagia symptoms indicate dysphagia is bolus-specific, swallow of the problem bolus (including capsules or tablets) can be observed. Similarly, if dysphagia symptoms vary with position, this can be systematically observed during fluoroscopy.

Tasks Not Requiring Additional Contrast

If introduction of additional boluses appears too risky, swallow and non-swallow behaviors that do not require contrast can be observed. For example, speech tasks targeting behaviors important to swallow can be observed (i.e., “k” repetition to assess posterior linguopalatal valving, sustained sibilants and repeated plosive+vowel syllables (ka, pa) to assess velopharyngeal valving). Nonspeech tasks might include effectiveness of hawk-spit to clear the pharynx, or cough to see if material in the larynx or trachea can be cleared. In
the A/P view, tasks requiring blowing against resistance can reveal asymmetry in lateral wall tone, if unilateral weakness is suspected.

**COMPENSATION OR FACILITATION BY CHAMBERS AND VALVES**

**General Principles**

If abnormalities in timing, clearing, and/or valving have been detected during the standardized protocol, compensatory strategies targeting the specific impairment are systematically explored. The ability of the clinician to apply compensations or facilitations during the DSS is dependent on ongoing interpretation of swallow biomechanics, and identification of effective and defective components (see Chapter 15). Compensation and facilitation strategies are aimed at maximizing intact components and minimizing or avoiding failures. Strategies include:

- changing the size and relationships of pharyngeal spaces and structures;
- changing the effects of gravity on bolus flow; or
- increasing effort to increase range, timing, or vigor of swallow gestures.

The effectiveness of the strategy should always be compared to the performance on the task where failure is noted. For example, if head turning is used to reduce residue, the success of the compensation can only be compared if the head is returned to the original position, and the swallow repeated. Additionally, the effectiveness of the strategy can only be assessed if the goal of the strategy is clear. For example, the goal of head rotation may be to clear hypopharyngeal residue, avoid it in the first place, or both.

The compensatory tasks or strategies available to a given patient depend on cognition; upper aerodigestive tract sensory integrity; head or neck oral, pharyngeal, and laryngeal anatomy and range of motion, control, and strength; respiratory health or resilience; and upper-body postural stability and control. Again, because progression through both the standard protocol and exploration of strategies involves constant risk assessment, this information must be compiled before the DSS.

**Compensations of Oral Chambers and Valves**

Because many observations of the mouth can be made without fluoroscopy, the DSS is most valuable in assessing the competence of the posterior oral cavity (OC). Nevertheless, inadequate oral bolus management has implications for airway safety; all observations are thus valuable in combination with clinical findings. In the OC, a bolus is prepared, created, and maintained as it is transferred toward the pharynx. These competencies are dependent on lingual shaping and agility of a muscular floor within a hard-walled chamber of bone and, usually, teeth. Successful oral transit also requires sensation for judgment (bolus readiness in consistency and size) and mucosal wetness.

When ability to control and propel the bolus in the oral cavity is poor,
Lubrication

The health of oral, pharyngeal, laryngeal, and esophageal mucosa and the presence and condition of saliva is not assessed directly by fluoroscopy, but can have dramatic effects on swallow timing and clearing performance (see Chapter 2).

Bolus Characteristics

In addition to size and thickness, multiple variations of bolus taste, texture, viscosity, and temperature facilitate or complicate timing, valving, and clearing performances during swallow. The potential for variation should be considered when interpreting swallowing performance. Normative data on performance during a standard set of swallow tasks is valuable because fluoroscopy time constraints prevent exploration of the infinite combinations of food, drink, and saliva that a dysphagic patient may face. (See Chapter 18 for a discussion of the therapeutic use of these types of variables in dysphagia management.)

COMPETING BEHAVIORS AND STATES

Multiple behaviors and states share with, or affect responses of, the oral, pharyngeal, and laryngeal structures during swallow: Gagging, sneezing, hiccupping, laughing, crying, speech, startle, fear—essentially any distraction—can affect swallow performance. Clinician direction during the fluoroscopy studies should take this into account.

Environmental Variables

Some environmental circumstances, even the presence of pictures (Maeda, Ono, Otsuka, Ishiwata, & Kuroda, 2004), promote interest in eating or drinking but others do not. The fluoroscopy suite likely represents the latter category for most people. The influence of environment is one of the many reasons why we do not consider the fluoroscopic swallow study a feeding assessment.

Adaptability

In view of the number and complexity of variables affecting swallow, adaptability must be a signature characteristic of the normal swallow. Indeed, when a swallower’s ability to adapt is overwhelmed or unavailable, dysphagia results. Evidence of spontaneous adaptability is one of the most important pieces of information available on fluoroscopic swallow studies. Clues to patient awareness of real or potential swallow failures can be inferred from behaviors that could be called precautionary, protective, or adaptive. Cough in response to aspiration or supraglottic penetration is the most recognized protective response, but there are spontaneous preventative behaviors less appreciated (e.g., early lingual retraction and early laryngeal closure among them). Spontaneous compensations have been observed for many years (Bosma, 1957a, 1957b) and more recently encouraged. Observations of older non-dysphagic patients who demonstrate change in swallow performance with age support the idea that adaptability of swallow movements is essential.
Conversely, recognition of a patient’s maladaptive or excessive responses during fluoroscopy, leads to more appropriate intervention. With evidence of good adaptability in a dysphagic patient, both swallow assessment and therapy can be more aggressive.

CHAMBERS DIVIDED BY VALVES—A PERSPECTIVE FOR ANALYSIS

Analysis of the oral, pharyngeal, and laryngeal spaces as a series of mutable chambers (tubes or cavities) and valves is an accepted tool for the analysis of speech or voice (Fant, 1970, 1980; Flanagan, 1972). Kennedy and Kent (1985) proposed a similar model of tubes and valves for description of swallow. They divided the oral and pharyngeal chambers based on spatial orientation (horizontal and vertical), the differences in their function, and on the presence of a functional valve between them, the posterior linguopalatal or retro-oral valve (Bosma, 1957a, 1957b). We have found this model to be valuable in approaching analysis and interpretation.

During analysis of fluoroscopic studies, we have also found it insightful to further subdivide the pharynx into the oropharynx (mesopharynx) and the hypopharynx (laryngopharynx). In our experience conducting and analyzing fluoroscopic swallow studies, this division has become apparent to us in the following ways:

- Airway threat escalates significantly as the bolus passes from one chamber to another. Contrast retained in the oral cavity is least likely to be aspirated and most easily expelled. Contrast retained in the oropharynx is more threatening, but can be expelled by hawk-spit or suctioned fairly easily. Contrast retained in the hypopharynx cannot be voluntarily expelled unless it is at the entry to or in the larynx (and cough is effective) and it is very difficult to suction. Awareness of the progression of risk is helpful when directing the swallow study.

- The oropharynx and hypopharynx differ in their actions for swallow. Bolus flow through the oropharynx is normally mid-line propelled by the retracting tongue and the medializing constrictors. In the hypopharynx, bolus flow is deflected around the larynx, primarily laterally, by the epiglottis as the pharynx foreshortens to engulf and draw the bolus distally.

- Finally, in our experience, patients appear to use the mid-pharyngeal deflecting structures, the valleculae/epiglottis as a functional valve, the opening and closing of which can be controlled, if need be. Certainly, patients lacking the means to control, even stop, the bolus at that point are severely impaired.

In any case, as noted, we have found the perspective of the oral, pharyngeal, and laryngeal spaces as a series of
chambers and valves a useful model in our analysis and interpretation of the fluoroscopic swallow study. What follows is a discussion of our approach to analysis and interpretation using this model.

**DSS Analysis: Bolus Transit Time Versus Swallow Gesture Times**

The goal of swallow gestures (movements of the chamber and valve structures) is to move the bolus quickly and completely from the mouth, through the pharynx, and into the esophagus, without leaks into the trachea or nasopharynx (or backflow into the mouth from the pharynx or into the pharynx from the esophagus). DSS analysis considers swallow gestures separately from their effects. In this case, timing of swallow gestures is considered separately from timing of bolus transit through the pharynx. (See detailed discussion in Chapters 16 and 17.)

Comparing timing of swallow gestures with timing of bolus positions reveals breakdowns in sequence that are associated with increased aspiration risk, for example, arrival of the bolus in the PES more than 0.10 sec before completion of supraglottic closure (Kendall, Leonard, & McKenzie, 2004a, 2004b; Leonard, unpublished data). Gestures timing versus bolus transit timing highlights competent, as well as failed, performance. An excellent example of this is a swallow in which the bolus moves no further than the oropharynx (i.e., remains in the valleculae), while hypopharyngeal swallow gestures (including hyoid and laryngeal displacement and PES opening and closing) continue on in a timely manner. Although it is true in this case that the swallow has failed to be effective (in transferring the bolus to the esophagus), it must be said that a swallow sequence was completed. The distinction between gestures and their effects helps to specify incompetent gestures while appreciating competencies: information that is valuable in planning treatment and developing prognoses.

**DSS Analysis: Displacement**

DSS analysis offers tools to determine whether range of motion (apart from time) of some critical swallow gestures is normal for age and gender. Distinction between range of movement and timing of movement clarifies whether failure of a component is due to poor movement, or to lack of coordination of movements with each other or with position of the bolus as it moves through the pharynx. Movements chosen to be measured (e.g., hyoid and laryngeal displacement, opening of the pharyngoesophageal segment [PES]), pharyngeal space obliteration, are difficult to judge subjectively, but readily lend themselves to objective measurement. Measures of hyoid and laryngeal displacement target individual structures. PES opening and pharyngeal clearing measures are comprised of movement of multiple structures with a single goal (i.e., expansion of the PES and obliteration of the pharyngeal chamber space).

**DSS Analysis: Discussion by Chamber and Valve**

As noted earlier, DSS analysis begins by describing each chamber in terms of...
INTRODUCTION

This chapter is divided into two main sections. First, a brief history of our team’s use of objective measures obtained from dynamic swallow studies (DSS) will be presented. Though we have subsequently used these measures for research purposes, our initial interest in them arose primarily from a shared dissatisfaction with the credibility of our fluoroscopy (DSS) interpretation and recommendations for treatment, based as they were on subjective observations. Even though our team included very experienced medical, surgical, and radiology professionals, as well as speech pathologists and nurses, no one at that time had broad experience in observing and interpreting these types of evaluations. As soon as objective measures appeared in the literature, we incorporated them in our patient studies. As more information was published on swallow and as our experience grew, we adjusted and developed new measures to reflect new developments in the literature, our understanding of swallow and the particular problems presented by the head and neck cancer population. Our experience in this pursuit may be of interest to other clinicians, and is included here for this reason.

In the second portion of the chapter, the specific measures we collect, and
the rationale for each, will be dis-
cussed. Normative values and reliabil-
ity data for each measure will also be
provided, as will differences according
to age, gender, and bolus size or consis-
tency. Our own experience with the
clinical utility of particular measures
will also be discussed.

BACKGROUND AND RATIONALE

The Path to Objective
Measures

Our interest in making objective mea-
sures started at about the same time our
team began meeting weekly to discuss
patients. In reviewing their dynamic
swallow studies, it became apparent
that we sometimes disagreed about
what we were seeing, even when we
watched a recording repeatedly, and in
slow motion. In general, and consistent
with many subsequent literature reports
(Ekberg et al., 1988; Gibson & Phyland,
1995; Karnell & Rogus, 2005; Kuhle-
meier, Yates, & Palmer, 1998; McCul-
lough et al., 2001; Perlman, Booth, &
Grayhack, 1994; Scott, Perry, & Bench,
1998), we were usually in agreement
for binary observations, for example,
whether or not there was aspiration,
penetration, velopharyngeal reflux, or
significant post-swallow residue. Swal-
lows that appeared greatly prolonged
typically produced consensus, as well.
Times that were possibly prolonged, on
the other hand, were problematic. For
other observations—how normally did
the hyoid move, the pharynx constrict,
or the pharyngoesophageal segment
(PES) open—our judgments frequently
differed. Beyond our problems with
subjective reliability, and in fact even
when we did agree, there was a strong
feeling within our team that, without
objective information, our impressions
and recommendations lacked credibility.

In the interest of harmony, improved
objectivity, and enhanced credibility,
we searched available resources for in-
formation that would lead to improved
assessments. We had been performing
fluoroscopy studies in our craniofacial
anomaly patients, and referred fre-
quently to the cephalometric literature
for help in evaluating velopharyngeal
function in a quantitative manner. When
the fluoroscopic evaluation of swallow
was introduced by Logemann and her
colleagues (Blonsky, Logemann, Boshes,
& Fisher, 1975; Logemann, 1983; Loge-
mann, Boshes, Blonsky, & Fisher, 1977),
we recognized that it also lent itself
to quantitative analysis. We adopted
Logemann’s recommended protocol
with its emphasis on standardization,
and have been employing it with little
change ever since. With the exception
of some work on timing, however, which
began to emerge in the 1980s, quantita-
tive guidelines pertinent to swallowing
were slow to emerge. Though limited,
the data available were quite useful;
very quickly, we added timing infor-
mation to our studies.

Initially, we used conventions de-
scribed by Logemann (1983) for mea-
suring transit times, but the parameters
she was using were not always present
or identifiable in our studies. For ex-
ample, the faucial pillars were not easily
visualized, and neither the angle of the
mandible nor the faucial pillars were
always present in patients who had
undergone head and neck resections.
In time, we modified our scheme to
facilitate measurement, in particular, in our head and neck population. Our first effort to collect normative timing data was in a group of 16 adults who were undergoing upper gastrointestinal (GI) studies for distal esophageal GI complaints (unpublished data, 1988; Johnson, McKenzie, Rosenquist, Liberman, & Sievers, 1993). The resulting data were consistent with those reported by other investigators (Cook et al., 1989; Curtis, Cruess, Dachman, & Maso, 1984; McConnel, 1988a, 1988b), and our standard deviations were small, which encouraged us to move forward.

Soon after adding timing information to our studies, we explored possibilities for displacement measures. Our explorations led us to strategies for getting video images into a computer (or “digitizing” them). Fortunately, the technology for doing this easily, relatively inexpensively, and effectively improved just as our interest piqued. Once the digitization problems were solved, we worked on techniques for measuring hyoid displacement and PES opening. When several members of our own team, as well as outsiders recruited for the task, made measurements that demonstrated good inter- and intrajudge reliability, we again felt we were moving in the right direction. As always, we incorporated measurements into routine patient assessments and our measurement techniques reflect this perspective. When our data appeared comparable to values reported by other investigators using different techniques (Cook, 1993; Dantas et al., 1990; Dodds, Man, Cook, Kahrilas, Stewart, & Kern, 1988; Dejaeger, Pelemans, Ponette, & Joosten, 1997; Ekberg, 1986; Jacob, Kahrilas, Logemann, Shah, & Ha, 1989; Kahrilas, Dodds, Dent, Logemann, & Shaker, 1988; Perlman, VanDaele & Otterbacher, 1995), our confidence improved further.

**Normative Data**

Ultimately, we collected additional normative data, using the same equipment and measurement strategies we used for patients. In time, we performed fluoroscopy studies on large groups of younger and more elderly normal subjects, respectively (Kendall, 2002; Kendall & Leonard, 2002; Kendall, Leonard, & McKenzie, 2001; Kendall, Leonard, & McKenzie, 2003; Kendall, Leonard, & McKenzie, 2004a, 2004b; Kendall, McKenzie, Leonard, Gonsalves, & Walker, 2000; Kendall, Leonard, & McKenzie, 2004a, 2004b; Leonard, Kendall, McKenzie, Gonzales, & Walker, 2000). As a team, we were now able to use our particular measurement scheme to compare patient data to nondysphagic subjects according to age and gender. Observations from these studies also provided us with a much better idea about normal variability, and of the range of behaviors, both times and displacements, that characterize normal swallow. Normative data for the measures we obtain, for adults younger than 65 years of age, and for a more elderly population of adults over 65 years, are presented in Table 16–1.

**Data Display**

Having now worked out strategies for both timing and displacement measures, and having collected these measures
TIMING AND DISPLACEMENT MEASURES

The measures described in this chapter represent our current best thoughts about what types of data are usefully obtained from the dynamic swallow study (DSS). They reflect our “borrowings” from other clinicians and investigators, as well as many of our own conventions, and over time have proven useful to us in assessing our patients (Crary, Butler, & Baldwin, 1994; Dejaeger, Pelemans, Ponette, & Joosten, 1997; Dengel, Robbins, & Rosenbek, 1991; Logemann, Kahrilas, Begelman, Dodds, & Pauloski, 1989; Perlman, VanDaele, & Otterbacher, 1995). But we also believe strongly that a great way to study swallowing, normal and disordered, is to try to “measure” it. The dynamic swallow study affords a unique opportunity to do this, to sample and quantify at least some events that are critical to the complex swallow sequence. It is in the interest of the study not only as an excellent diagnostic and treatment planning tool, but also as a tool for learning, that this chapter is included.

Once familiar with the strategies used, readers will be able to make their own measurements from the sample swallow studies included in the Chapter 17 materials folder, and to compare their results with ours. Shareware programs used in analysis, for both PC and Mac computers, are also included in this folder. In addition, an animated tutorial, “DSSTUTOR” is included on disk to facilitate the mechanics of measurement. Once you have gone through the tutorial, and read this chapter, it will be relatively simple to have both “DSSTUTOR” and the program for making measures open at the same time on the monitor. You can watch us make a measurement and then try it,
yourself. For readers who are currently involved in performing and analyzing studies, comparisons to the scheme used in our setting may be of interest. For readers who have not had extensive experience with the dynamic swallowing study, the materials provided should represent an in-depth introduction to the value and potential of this assessment tool, as well as to a number of issues that befuddle both clinicians and investigators working in this area.

**HARDWARE AND SOFTWARE**

**Timing Measures**

A good quality videocassette recorder (VCR) with stop frame and slow motion reverse and forward capabilities has for many years been the basic component for review and analysis of dynamic swallow studies, and still works well. With an accurate frame advance feature, the time between two events can be calculated simply (if tediously) by determining the number of frames between them, recognizing that each frame is equal to 1/30th of a second. Rapidly, however, VCR technology is being replaced by digital recording systems. Consequently, the methods discussed here, and materials provided for readers, will be primarily directed to digital media.

Our DSS studies are currently recorded on a Sony DVO-1000MD (Sony Corporation of America, New York City, NY) digital video recorder (DVR) using DVD+RW disks. Timing information in hundredths of a second is recorded on the disk from a timing generator interfaced between the x-ray camera and the DVR during filming of the study. Several timing generators will serve this purpose. One used at our Center is the Horita Video Stopwatch VS-50 (Horita, Mission Viejo, CA). The cable coming from the x-ray camera (same one usually attached to the VCR or DVR) is attached to the “video in” port of the Stopwatch. A second cable is then attached to the “video out” port on the back of the timing device. The other end of this cable is connected to the “video in” port of the DVR. By interfacing the timer between the fluoro and the recorder in this manner, timing information can be superimposed on the recording. The user has the option of where to position the timing information on the monitor, and of adjusting the size and color of the numeric display. The ability to place the time signal in different positions, that is, all four corners, on the disk is a desirable feature in whatever generator is used. If timing information can only be positioned in one location on the screen, it may occasionally cover up events or landmarks in the x-ray study that are critical to visualize.

With the timing generator activated, timing information will appear on the monitor. Because timing information will appear on every frame recorded, it is not necessary to start every swallow attempted by a patient at time “0.” Our typical practice is to just turn on the timer when we begin recording, and to leave it on throughout the study. All timing measures are then calculated from whatever time marks the beginning of an event, to the time that marks the end of the event.

Once the study is recorded, there are several options for playback of the DVD disk. A stand-alone DVD player (or player-recorder) may be used.
tively, any computer with a DVD drive is sufficient for this purpose. In either case, the particular disks used for recording must be in a format the drive or player can read, for example, DVD+RW, DVD-R (disk included with this text is DVD+RW). Most computers are also equipped with software programs that permit playback of the DVD (“Windows Media Player” for PC, “DVD Player” for Mac). A PC program that we use is “WinDVD” (Intervideo, Fremont, CA). The particular value of “WinDVD” is the great flexibility it permits the user in manipulating the recorded study, including variable playback speeds in forward and reverse, frame advance, and options for adjustment of the video image (contrast, brightness, etc.). Viewing the study in this manner, we attempt to identify and note the times described in Table 17–1, all of which are made from the lateral view x-ray. Typically, we acquire these times for a 1-cc bolus, and for the largest bolus swallowed. As previously described, both bolus transit and swallow gesture times are noted.

Once the timing events have been determined, it is also possible to calculate durations of critical events during the swallow. In our scheme, the following durations are considered of interest:

**Oropharyngeal transit time**—duration of bolus transit through the oropharynx, from the posterior nasal spine ($B_1$) to the time of bolus exit from the valleculae ($B_2$).

**Hypopharyngeal transit time**—duration of bolus transit through the hypopharynx, from the time the bolus head exits the valleculae ($B_2$) to the time of bolus tail clearance of the PES ($B_P$).

**Total transit time**—sum of oropharyngeal and hypopharyngeal transit times ($B_P-B_1$).

**PES opening time**—time from PES opening to PES closing ($Pcl-Pop$).

**Airway closure time**—time supraglottic airway remains closed during the swallow ($Em-AEc$).

**Hyoid maximum duration time**—duration of maximum hyoid displacement ($H_3-H_2$).

### Displacement Measures

Displacement measures are obtained in one of two ways, depending on whether a VCR or DVR is used. If recordings are on videotape, then the images of interest, that is, selected frames from the study, are first digitized so that they can be manipulated by a computerized image analysis program. In our setting, videotaped images are input to either a Macintosh (any one from a Mac 11 to current generation) or PC/Pentium or newer style computer using digitizing boards from Data Translation, Inc. (Marlboro, Massachusetts) or Scion Corporation (Frederick, Maryland).

A cable from the VCR attaches to the digitizing board in the computer so that, when you open the software program and set it to “Capture,” images from the VCR monitor also appear on the computer screen. The software program used for capturing images obtained in this manner is “IMAGEJ.” It was developed by Wayne Rasband and his
a care facility. Another may be seriously impaired at the time of evaluation, but be expected to recover, perhaps fairly rapidly, to a normal or near-normal level of function. The impact of treatment recommendations on human resources (caregivers and their capabilities), as well as on technical resources (obtaining and preparing particular food types) must be considered. The team makes every effort to provide preliminary recommendations and precautions for safe feeding as soon as sufficient information is available. In some instances, however, additional diagnostic studies are required before a treatment plan can be finalized. Such studies may be necessary to establish a medical diagnosis, when this is in question, or to further elaborate or treat a problem that has been identified. In infants and young children, special studies are frequently required before interpretations of findings, and treatment recommendations, can be completed. Some of these were discussed at greater length in Chapter 9. Commonly requested studies, however, include neurodevelopmental assessment and communication skills evaluation. In infants, pulmonary workup is often needed to determine the adequacy of respiratory support for swallowing.

Initial team recommendations may also include a referral of the patient to other medical specialists for further evaluation. For example, if there are concerns about esophageal function in swallowing that have not been addressed, or about the possibility of serious gastroesophageal reflux disease, referral to gastroenterology is indicated. Questions about neuromotor integrity or sensation that have not been previously raised warrant referral to neurology. Issues regarding laryngeal function are most often considered prior to the team evaluation; if not, an otolaryngology referral is generated. Similarly, concerns about dentition or oral hygiene may warrant a dental evaluation. Very often, the team finds it advisable to secure a dietary consult. This recommendation is so often critical, that, in fact, an entire chapter in this manual has been devoted to nutritional evaluation of patients with dysphagia. In our experience, the advantage of having a network of specialists who act as an extended part of the dysphagia team is extremely useful. These specialists are familiar with team functions and objectives, have had experience with patients with similar problems, and are typically willing to see patients as expeditiously as possible.

**TREATMENT PLAN**

Dysphagia team recommendations directly related to the management and treatment of dysphagia fall into several categories. For our purposes, treatments can be classified as behavioral, medical, or surgical. Examples of these treatments, and the indications for prescribing them in individual patients, or particular groups of patients, are discussed next.

**BEHAVIORAL THERAPIES**

A therapist specializing in oropharyngeal swallowing disorders, most often a speech-language pathologist, provides behavioral therapy to patients suffering from dysphagia. Physical therapists and occupational therapists may also provide swallowing therapy, and/or other therapies of value. For example, a physical therapist may be consulted
when there are concerns about a patient’s head/neck or body posture in support of respiration and swallowing, or about appropriate seating during eating. Occupational therapists may become involved in rehabilitation of motor skills required for a particular function related to eating, as in the use of feeding utensils or adaptive devices used for this purpose. In some instances, nursing professionals also participate in swallowing therapy. In hospitals and other care facilities, the combined efforts of the swallowing-disorder therapist and nurses charged with a patient’s care may be used to “mass” patient trials with various therapeutic strategies, and to monitor a patient’s response to these strategies.

In general, behavioral therapies are recommended when the strength, endurance, and/or mobility of structures involved in swallowing are diminished, and when diagnostic probes have indicated that swallowing may be facilitated, or made safer, by bolus manipulation, postural compensations, facilitative maneuvers, or adaptive devices. Behavioral therapies are also recommended when it is believed that a more appropriate initiation or timing of certain swallowing events may be induced by selective stimulation of particular structures or systems. Summaries of the rationale and objectives for each of these interventions, and examples of each, are presented here.

**Improving Strength/Mobility/Endurance of Structures**

Related to the model of swallowing discussed in earlier chapters, exercise is directed to improving the effectiveness of valves and chambers involved in swallowing (i.e., lip seal, breath holding, pharyngeal constriction). Indications for therapy directed to improving the strength, range of motion, endurance, and agility of the gestures involved include clear evidence of weakness or limited movement of the mandible, lips, tongue, pharynx, larynx, or pharyngo-esophageal segment. Specific examples of this type of problem include failure to contain bolus material in the mouth related to an inability to maintain lip closure, or failure to protect the airway related to an inability to elevate the larynx or close laryngeal valves. Such findings are typical of certain patient populations, for example, patients treated with radiation therapy for head and neck cancer, or patients with muscle weakness secondary to neurogenic disease. Poor structural mobility and muscular weakness should be documented by the physical examination and confirmed with diagnostic studies such as the dynamic swallow study (DSS). Specific exercises should be aimed at improving the capabilities of residual swallowing gestures, and/or those with the most compensatory potential.

A number of swallowing exercise programs have shown promise in recent years. One described by Shaker et al. (1997) demonstrated increased pharyngo-esophageal (PES) opening in normal elderly adults and in a group of nonoral patients with dysphagia with abnormal PES function (Shaker et al., 2002). The specific exercise involves lying on the back and elevating the head sufficiently to observe the toes without moving the shoulders. Both sustained head elevation and repetitive elevations are used. The authors reported that normal elderly adults who did the exercise three times a day for a