2 Physiology of Swallowing

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Introduction

The upper digestive tract, consisting of the oral cavity, larynx and pharynx supports the physiology of swallowing in addition to respiration, phonation and articulation [1]. To carry out each of these functions and for the rapid shifts between them, the upper aerodigestive tract has a series of valves that are tuned differently for each function [1].

Swallowing or deglutition involves the passage of liquid or a food bolus from the oral cavity to the stomach through the pharynx and esophagus, over the entrance to the laryngeal vestibule [2]. Swallowing is a complex neuromuscular function involving structures in the oral cavity, pharynx, larynx and esophagus, requiring coordinated activity of muscles in these regions [3–7]. During deglutition, the valves in the oral cavity and pharynx are adjusted to direct the flow of food efficiently and safely. At the same time, pressure is exerted on the liquid or food to move it rapidly, without leaving any significant residue in the mouth or pharynx. This complex sequence of motor behaviour is partly under voluntary control and partly under reflexive control [4, 6].

Several researchers have described normal swallowing physiology in four stages: the oral preparatory stage, the oral stage proper, the pharyngeal stage and the esophageal stage [3–7]. The initial two stages, the oral preparatory and the oral stages, are under voluntary control, while the succeeding two stages, the pharyngeal and esophageal stages, are involuntary, being under reflexive control [8, 9]. The present opinion in literature is that the pharyngeal stage of swallow is not a reflex but a programmed activity where the motor program varies with the characteristics of the bolus being swallowed, voluntary control and other as yet undefined parameters [1]. There are six valves that operate during swallow within the upper digestive tract (Fig. 2.1) [1]: the lips, tongue, the glossopalatal valve (soft palate to the back of the tongue), velopharynx (soft palate to the posterior pharyngeal wall), larynx and the upper esophageal (cricopharyngeal) sphincter [1].

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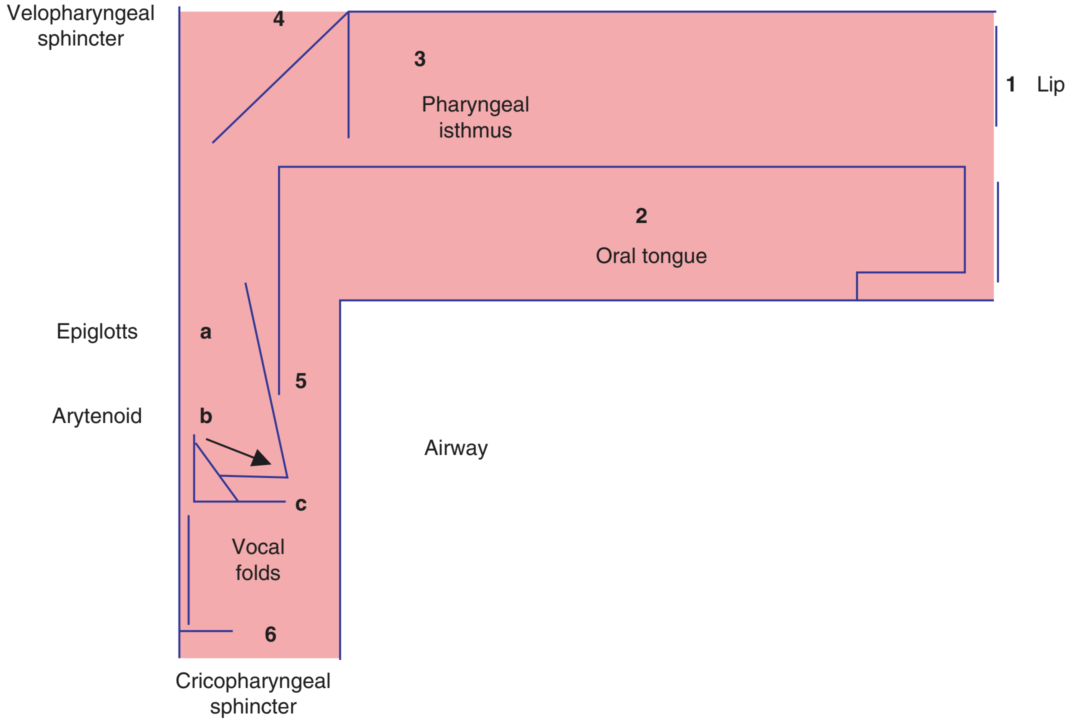

Fig. 2.1 Diagrammatic view of the oral cavity and pharynx with six valves. 1. lips; 2. tongue; 3. soft palate to tongue; 4. velopharynx; 5. larynx including the (**a**) epiglottis, (**b**) arytenoid to the base of the epiglottis and (**c**) true vocal folds; and 6. cricopharyngeal sphincter [1]

Stages of Normal Swallow

Swallowing is a continuous process involving voluntary control and programmed stages, generally split by convention into three distinct phases: oral, pharyngeal and esophageal.

Voluntary Stages of the Swallow

Oral Phase

Oral phase is divided into two stages: (1) oral preparatory stage and (2) oral phase proper.

Both the phases are voluntary, can be started at will or can be reflexively elicited by stimulation of areas of the mouth and pharynx.

Oral Preparatory Stage

The oral preparatory prepares food for the swallow. It involves the coordination of (1) lip closure to hold food in the mouth, (2) tension in the labial and buccal muscles to close the anterior and lateral sulci, (3) rotatory motion of the jaws for chewing, (4) lateral rolling motion of the tongue to place the bolus on the teeth during mastication and (5) forward bulging of the soft palate to close the oral cavity posteriorly and widen the nasal air way [7]. In oral preparatory phase, the jaw is closed by the elevators of the jaw, namely, the temporalis, masseter and medial pterygoid. The muscle action of chewing food utilizes a combination of depressors and elevators. Tight seal of the lip is maintained by the orbicularis oris, and the buccinators are used to bring back the food from the vestibule to the cavity during mastication. The soft palate is lowered by the action of palatopharyngeus and palatoglossus. These muscles approximate the arches to the dorsal posterior tongue. The airway remains open at this stage [2].

The oral preparatory stage is mechanical, involving reduction of solid food to a pulverized consistency that may be easily swallowed. The teeth are involved in chewing food, anterior incisor teeth provide cutting actions, and posterior molar teeth provide a grinding action. The muscles of the jaw working together can close the teeth with force as great as 55 pounds on incisors and 200 pounds on the molars [10]. The muscles of mastication, otherwise known as the elevators and depressors of the jaw, play a key role in bolus preparation before swallowing is initiated. The motor branch of trigeminal nerve innervates majority of the muscles of mastication, and the neurological control is by the nuclei in the brainstem. The rhythmical chewing movements are due to the stimulation of reticular areas in the brainstem taste centers. Furthermore, mastication occurs by the stimulation of regions in the hypothalamus, amygdale and cerebral cortex adjacent to the sensory regions for taste and smell. Much of the process of mastication is caused by a chewing reflex. The presence of a food bolus in the mouth at first initiates reflex inhibition of the muscles of mastication allowing the mandible to drop down. This drop, in turn, initiates stretch reflex of jaw muscles that leads to rebound contraction, which spontaneously raises the mandible to cause the closure of teeth, but it also compresses the bolus again against the lining of mouth, which inhibits the jaw muscles once again allowing the mandible to drop and rebound another time; this process is then repeated throughout the process of mastication [10].

Formation of the bolus is done by the tongue. The intrinsic muscles change the tongue shape, and the extrinsic muscles alter the position of the tongue in the oral cavity. These muscular actions are dependent on each other. Changes in the shape will produce changes in position and vice versa. Tongue flattening by the verticalis will also protrude the tongue because its bulk gets displaced. The downward movement of the tongue by hyoglossus muscle will also lower the sides of the tongue. The main neuromuscular activity involved in oral preparatory phase is the rolling motion of the tongue laterally. Without the normal range of tongue motion, the manipulation and mastication of food during oral preparatory phase would be impossible. The tongue and jaw muscle actions in bolus formation are helped by the lips in maintaining a seal. Buccinators help in returning the food the vestibule into the cavity. The soft palate helps in preventing nasal regurgitation [2]. Though patients will be able to chew with reduced lip closure, without teeth, with reduced buccal tension or with restricted jaw motion, they cannot chew without the normal tongue mobility. At the termination of oral preparatory phase, the tongue pulls the food together into bolus and holds it cohesively on the floor of the mouth against the hard palate, in preparation for the beginning of the oral phase of swallow (Fig. 2.2a, b) [5, 6, 11].

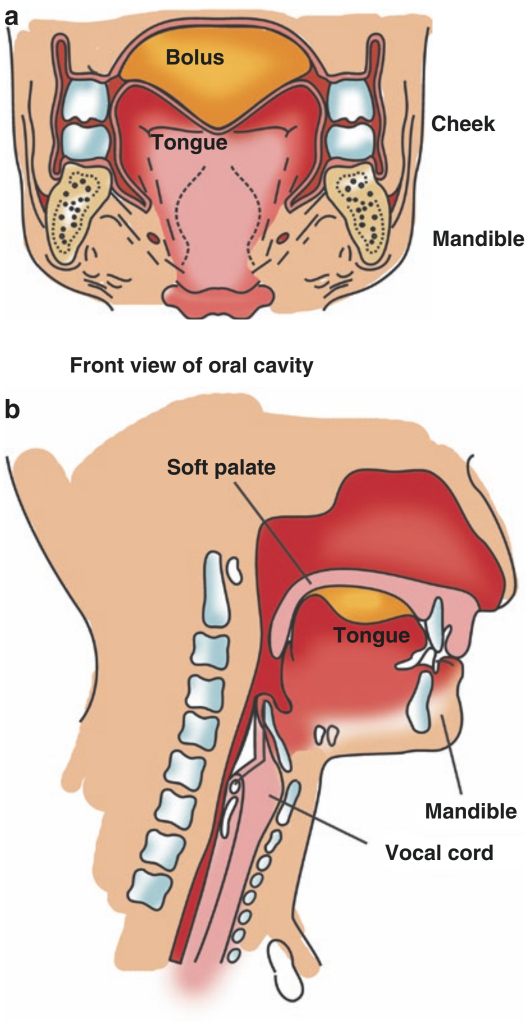

Fig. 2.2 (**a**, **b**) The anterior and lateral views of the tongue while holding a bolus immediately before initiating the oral stage of the swallow [11]

Oral Phase Proper

The oral stage of swallowing is voluntary and is designed to move the food from the front of oral cavity to the pharynx where pharyngeal stage of swallowing is initiated. From the pharynx onwards, swallowing becomes entirely autonomic involuntary which cannot be stopped. The tongue motion is the most critical element in this stage of swallow, because the tongue shapes, squeezes and lifts the bolus upward and backward along the hard palate until the food reaches the pharynx. During this backward propulsion by the midline of the tongue, the lateral margins of the tongue are closed against the alveolar ridge, providing resistance against which midline of the tongue propels the bolus. The tension in buccal musculature also contributes to propelling the bolus backwards, but to a much lesser degree than tongue movements. When the leading edge of the mandible crosses the tongue base, the pharyngeal swallow should be triggered in healthy people of all ages (Fig. 2.3) [11]. This pharyngeal swallow is usually triggered by glossopharyngeal nerve. In healthy subjects, the oral stage lasts about 1–1.5 s and is prolonged slightly with increasing age and with increasing viscosity of the bolus [5, 12].

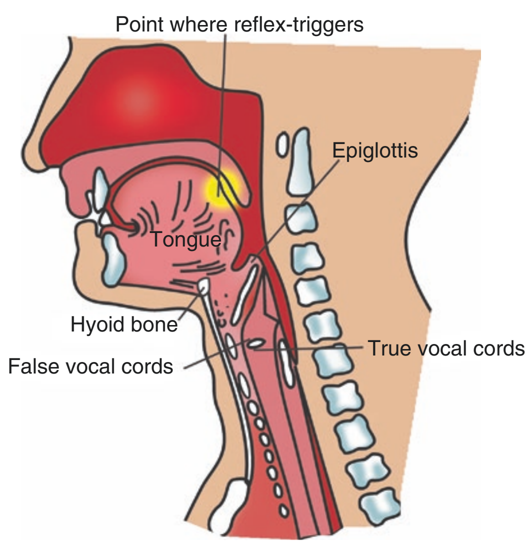

Fig. 2.3 Illustration of the lateral view of the head and neck depicting the point at which swallowing reflex is triggered [11]

Many distinct muscle actions are involved in the oral stage. The intrinsic muscles along with genioglossus raise the tongue blade and the tip towards the hard palate. Elevation of the mandible is essential for this. The mouth need not be completely closed during swallowing. It is difficult to swallow when the mouth is more open. Mandibular elevation assists the suprahyoid musculature in raising the hyoid, to change the height of hyoid. When the mandible is fixed, elevation of the floor of the mouth is associated with lifting the tongue by stylohyoid. Simultaneously the tongue gets flattened while the bolus moves back. As the food reaches the already deeply grooved back of the tongue, the soft palate is raised by the action of levator and tensor veli palatini. This protects the nasopharynx from the entry of food and closes the airway [2]. In some studies performed on animals and healthy humans, it has been found that the pharyngeal swallow is not only triggered by glossopharyngeal nerve but also from superior laryngeal nerve at the inlet of the larynx. Normal swallowing does not use the secondary mechanism of pharyngeal swallow because the bolus would have almost entered the airway when the pharyngeal swallow was triggered by this secondary mechanism [5].

Involuntary Stages of the Swallow

Pharyngeal Phase

Pharyngeal phase of the swallowing is physiologically more important because airway protection occurs during this stage in healthy individuals. By changing the consistency of food to liquid, by placing the food at the back of the mouth or with the head back position to cause the gravity to carry the food into pharynx, the preparatory and oral stages of swallow can be bypassed. However, the pharyngeal stage of swallow cannot be bypassed [13]. A series of events in the pharyngeal phase is initiated, as the bolus is moved back by the tongue to the pharynx (Fig. 2.4) [11]. The complex coordinated movements of pharyngeal phase last mostly for 1–2 s. Firstly, contraction of the diaphragm is inhibited making simultaneous swallowing and breathing impossible normally. During the same time, soft palate elevates to close the nasopharynx to prevent nasopharyngeal contamination. Vocal cords also start to close to protect the airways. The coordination between swallowing and ventilation is essential for airway protection [2]. The mechanics of pharyngeal stage of swallowing is so coordinated that simultaneous breathing and swallowing is prevented [14–18].

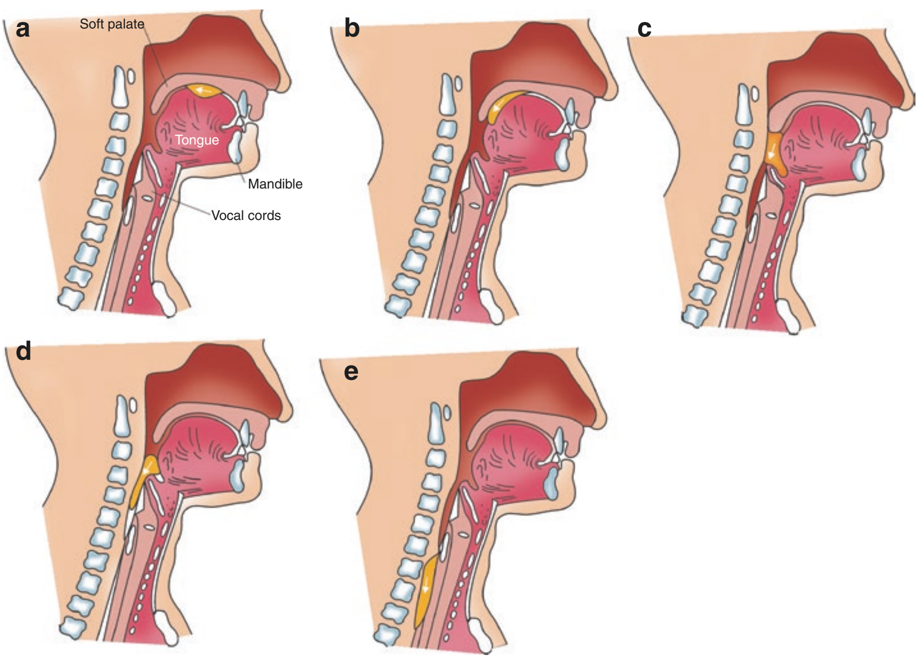

Fig. 2.4 Illustrations showing the progression of a bolus through the pharynx [11]

Neuromuscular Activities in Pharyngeal Swallow

The act of swallowing is generated by afferent impulses arising from mucus membrane lining of anterior and posterior pillars of the tonsils, soft palate, tonsils, posterior pharyngeal wall and epiglottis. The afferent impulses are transmitted via the sensory part of the trigeminal, glossopharyngeal and vagus nerves to stimulate the deglutition or swallowing centre located in floor of the fourth ventricle near respiratory centre in the medulla oblongata. The efferent fibres pass through motor fibres of trigeminal, glossopharyngeal, vagus and hypoglossal nerves to the pharynx [10].

As the food reaches the back of the mouth and oropharynx, it touches certain key trigger points. A reflex is then originated and the constrictors relax. This results in the dilatation of the pharynx. The larynx and pharynx are elevated by the longitudinal muscles. The bolus is then moved over the epiglottis by the constrictors contracting in sequence. The laryngeal inlet then closes by contraction of the muscles. Recent studies on simultaneous video fluoroscopy and endoscopy suggested that trigger point may be the summation of afferent signals for the entire sensory area of the oropharynx. Once the bolus has passed the arches, then swallowing is reflexive [2]. If triggering of the pharyngeal swallow gets delayed, none of these neuromuscular activities occur until pharyngeal swallow triggers: (1) velopharyngeal closure to prevent back flow of material into the nose, (2) tongue base retraction to propel bolus through the pharynx, (3) pharyngeal contraction to clear the residue through the pharynx, (4) elevation and closure of the larynx to protect the airway and (5) cricopharyngeal or upper esophageal centre opening to allow the bolus to pass into the esophagus [14, 19–25]. The neuromuscular functions overlap each other but do not all last for entire pharyngeal stage of swallow. Each activity lasts only if the bolus is passing that part of the pharynx. In pharyngeal stage, velopharyngeal closure and hyoid in laryngeal elevation occur as the first response, which triggers pharyngeal swallow (Fig. 2.5) [11]. This is followed by laryngeal closure which is then followed closely by opening of the cricopharyngeal sphincter. When the bolus reaches the middle to lower pharynx, the soft palate drops. At that time, the larynx is closed and elevated, and the upper esophageal sphincter (cricopharyngeus) is open, which prevents the passing bolus from entering the airway and allows it to enter the esophagus (Fig. 2.5). The duration of the pharyngeal stage normally lasts a maximum of 1 s and does not vary dramatically with the consistency of food, age or gender of the subject [5, 8].

The brainstem swallowing centre programs neuromuscular activities; hence some patients with head and neck cancer have damage to the peripheral sensory input to brainstem centre, which results in delayed or absent triggering of the pharyngeal swallow [26–29].

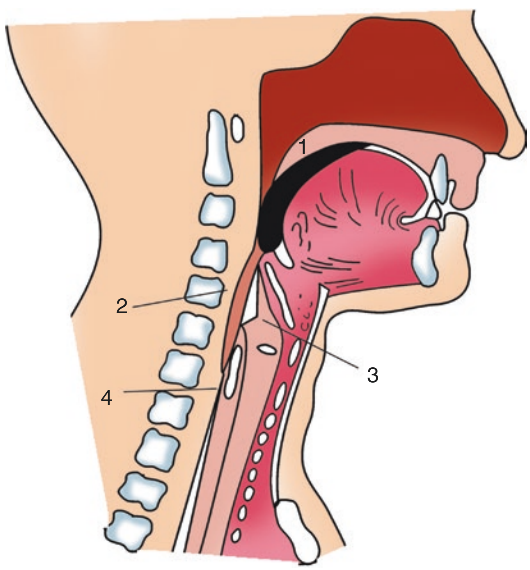

Fig. 2.5 Neuromuscular components in the swallowing reflex: (*1*) Closure of the soft palate, (*2*) peristaltic action, (*3*) elevation and closure of the larynx and (*4*) relaxation of the cricopharyngeus muscle [11]

Protection of the Airway

Protection of the airway during a swallow comprises of two components which are elevation and closure. Elevation is produced by contraction of strap musculature of the neck, which places the larynx upward and forward under the tongue base during its retraction at the completion of the oral phase of the swallowing (Fig. 2.6) [1]. The larynx is hauled up and away from the channel of the food bolus present over the base of the tongue.

Closure of the laryngeal inlet involves sphincteric action of laryngeal structures which are the epiglottis and aryepiglottic folds, the false and the true vocal folds [19–21, 30–34]. The relative importance of each of these sphincters has been debated in the literature [33, 35, 36]. Most researchers concur that the epiglottis and aryepiglottic folds perform a relatively minor role in protecting the airway, and their purpose is to divert food around the airway.

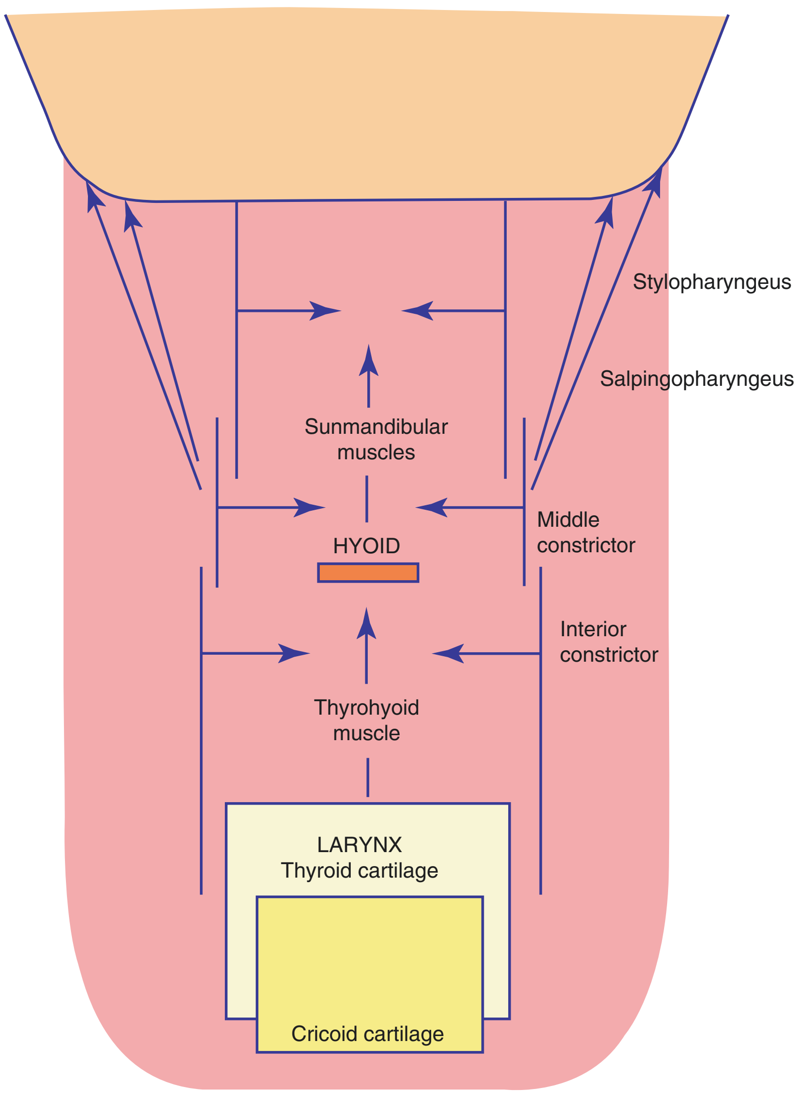

Fig. 2.6 Pharyngeal elevators (anterior view) and the directions of contractions during the swallow [1]

Opening of Upper Esophagus Sphincter (Cricopharyngeus)

The action of the cricopharyngeus muscle is in opposition to the function of the constrictor muscles of the pharynx. At rest, the constrictors are relaxed, and the upper esophageal sphincter (UES) is in a tonic contraction to prevent air passage into the esophagus concurrent with inhalation into the lungs. Additionally, the contracted UES or cricopharyngeus muscle prevents reflux of food from the esophagus into the pharynx [14]. During the swallow, as the constrictor muscles of the pharynx are contracting, the cricopharyngeus muscle relaxes at the precise moment. The anterior-superior movement of the larynx opens the cricopharyngeus muscle, and the bolus passes into the esophagus (Fig. 2.7) [1]. The duration of cricopharyngeus relaxation and airway closure increases as bolus volume increases [20].

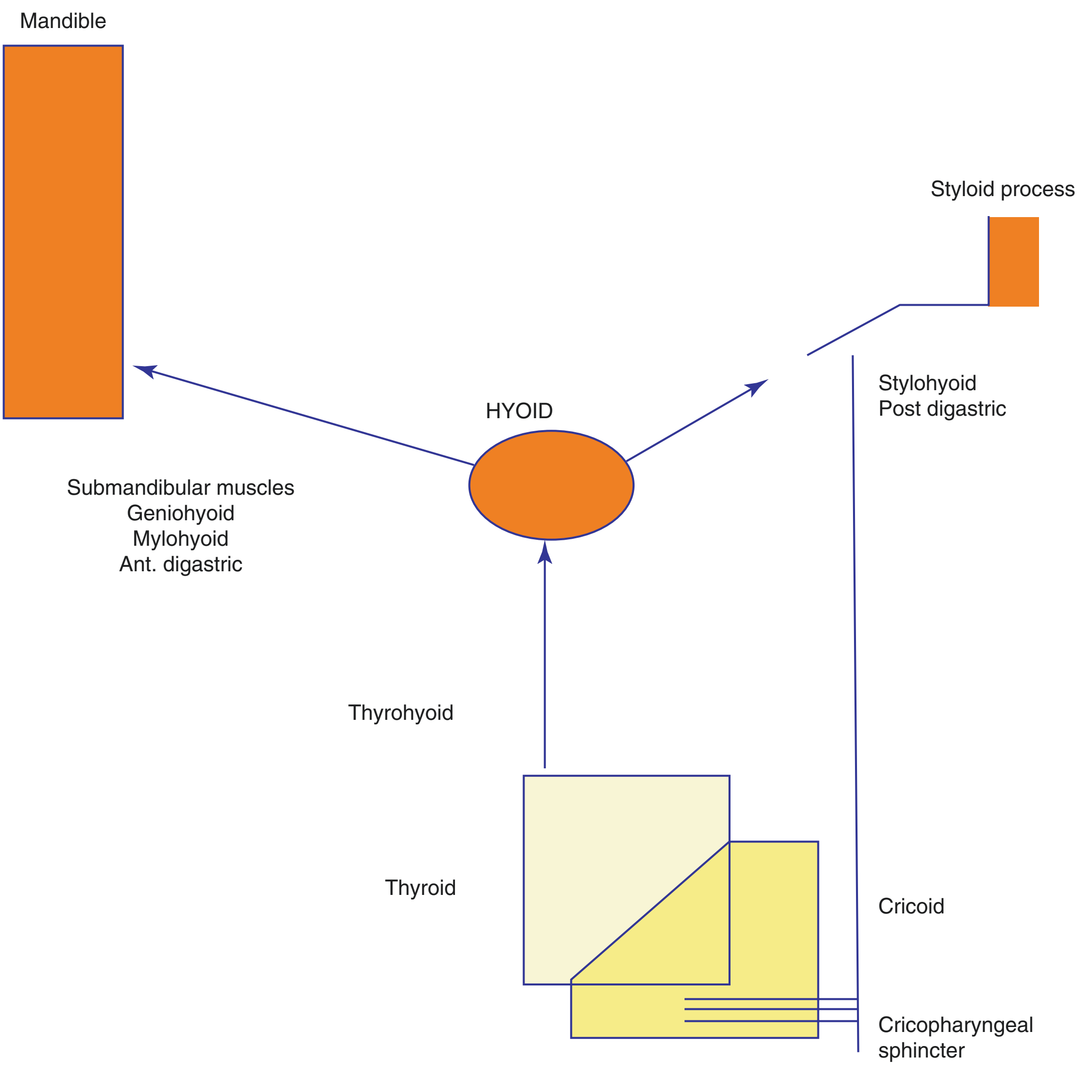

Fig. 2.7 Schematic representation of the hyolaryngeal suspension system and its relationship to the cricopharyngeus [1]

Pressure Generation Within the Pharynx

This component of deglutition is involved in the creation of pressure on the bolus to propel it from the mouth, through the pharynx and into the esophagus (Fig. 2.8) [1]. The oral tongue drives the bolus backward during the oral phase of swallow, lifts bolus and exerts pressure against the palate as it rolls the bolus towards the oropharynx [1].When the end of the bolus extends to the base of the tongue or vallecula, the tongue base rapidly moves backward like a piston, mounting the pressure in the pharynx. During the backward movement of the base of the tongue, the lateral and posterior pharyngeal walls at the tongue base level move medially and inward. The tongue base and the pharyngeal walls must make complete contact with each other. The larynx elevates almost 2 cm, and the pharynx is shortened by nearly 2 cm or one-third of its total length during the pharyngeal swallow in younger adults (under age 65). In older adults, this movement may be reduced by 0.5 cm. The pharynx raises with the larynx as it elevates [1]. This pharyngeal contraction or the squeezing action of constrictor muscles to move the bolus through the pharynx occurring sequentially is confirmed in electromyographic and radiographic studies. The pharyngeal contraction commences in the superior constrictor muscle and moves through the medial constrictor and to the inferior constrictor muscle (Fig. 2.8) [1, 21, 30]. Pharyngeal contraction is responsible for clearing food residue from the pharyngeal walls and piriform sinuses. When the food residue remains in the valleculae after the swallow, it is interpreted as a symptom of reduced base of tongue movement [21]. As the bolus volume increases, the base of tongue movement occurs later. If there is a unilateral weakness of the pharynx, food will remain in the pyriform sinus on the weaker side of the pharynx after the swallow. Furthermore, when both sides of the pharynx fail to contract, food will be left on either side of the pharynx within the piriform sinuses [1].

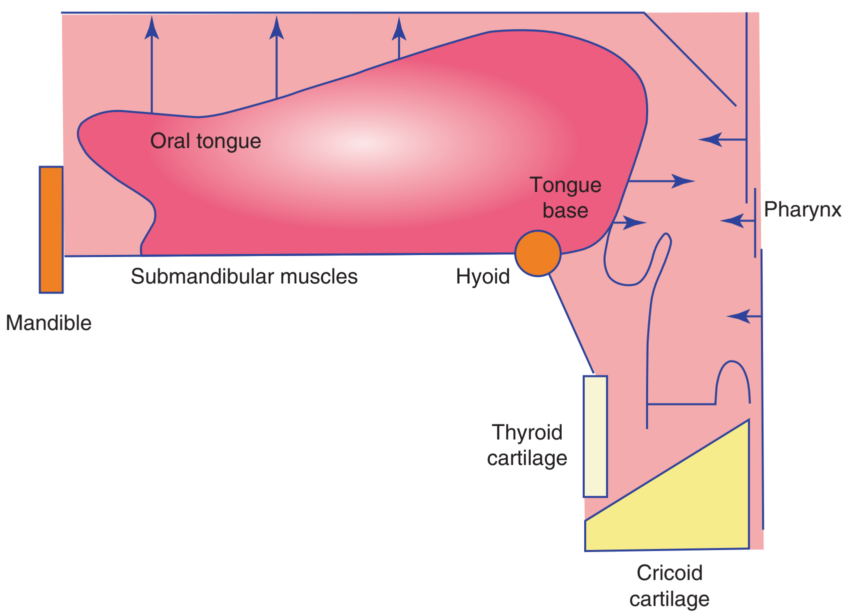

Fig. 2.8 Schematic representation of the pressure generators in the oral cavity and pharynx (oral tongue, base of tongue and the pharyngeal constrictors) [1]

Esophageal Phase

The esophagus is a muscular tube about 25 cm in length with an average diameter of 2 cm. In the resting state, the upper two-third of the esophagus is collapsed, while the lower one-third is rounded [8]. During the esophageal phase, the bolus of food is propelled from the cervical esophagus to the stomach by esophageal peristalsis which is aided by the gravity.

The esophagus normally exhibits two types of peristalsis, primary and secondary peristalsis. Primary peristalsis is a continuation of the wave that begins in the pharynx and spreads into the esophagus. When bolus has passed through the upper esophageal sphincter, this phase begins. The peristaltic wave passes all the way from the pharynx to the stomach in about 8–10 s. If the primary wave fails to move all the food that has entered the esophagus into the stomach, secondary peristaltic waves result from distension of esophagus itself by the retained food; these waves continue until all the food has emptied into the stomach. The secondary peristaltic waves are initiated partly by intrinsic neural circuit in myenteric nervous system and partly by reflexes beginning in the pharynx and are then transmitted upward through vagal afferent fibres to the medulla and back to the esophagus through glossopharyngeal and vagal efferent nerve fibres [10].

The pharyngeal wall musculature and that of the upper third of the esophagus are striated muscle. Therefore, the peristalses in these regions are controlled by skeletal nerve impulses from glossopharyngeal and vagus nerves. While in the lower two-thirds of the esophagus the musculature is smooth muscle, this portion of the esophagus is strongly controlled by vagus nerve and acts through connections with esophageal myenteric nervous system. When the vagus nerves through the esophagus are cut, myenteric nerve plexus of the esophagus become excitable enough after many days to cause strong secondary peristaltic waves even without support from vagal reflexes. Therefore, even after paralysis of brainstem, swallowing reflex, food fed by tube or another way into the esophagus will still pass readily into the stomach [10].

When the bolus has passed through the upper esophageal sphincter, the upper esophageal sphincter is formed by cricopharyngeal muscle approximately 3 cm in length, within the upper end of the esophagus. It is having high resting tone and is completely under control of vagus nerve. The esophageal stage has greater variability in duration than other stages of swallow. Normal esophageal transit time varies from 8 to 20 s [7]. After reaching lower two-thirds of the esophagus, the successive event is the opening of lower esophageal sphincter which acts as a valve to the stomach [11].

At the lower end of the esophagus, extending upward about 3 cm above its connection with the stomach, the esophageal circular muscle acts as a broad lower esophageal sphincter and is in a state of tonic contraction at rest. The musculature in the lower two-thirds of the esophagus is comprised of smooth muscle which keeps the walls in tight opposition. It is strongly controlled by the vagus nerves operating through communications with the esophageal myenteric nervous system.

Distension of the esophagus with the food causes reflex relaxation of the sphincter. When a peristaltic swallowing wave passes down the esophagus, there is a “receptive relaxation” of the lower esophageal sphincter before the peristaltic wave, which allows propulsion of the swallowed food into the stomach.

Once the bolus passes into the stomach beyond the region of sphincter, the lower esophageal sphincter closes and undergoes a strong prolonged contraction like a valve-like mechanism preventing regurgitation. Increased intra-abdominal pressure caves the esophagus inward at this point. Consequently, this valve-like closure of the lower esophagus helps to thwart elevated intra-abdominal pressure from driving stomach contents backward into the esophagus [10].

Effect of Swallowing on Respiration

Swallowing and respiration are intimately related. They use the same structures, and so, the two processes must be coordinated. Efficient transport of food and drink to esophagus must coexist with maintenance of safe airway [2]. Studies of normal individuals have reported that most common normal coordination involves interrupting the exhalatory phase of respiration with the swallow and briefly resuming exhalation after the swallow. The return to exhalation after the swallow is thought to increase safety, because the exhalatory airflow may assist in clearing any residual food or liquid from around the airway entrance. In contrast, interrupting the inhalatory phase of respiration with a swallow is thought to be less safe because the risk of inhaling residual food may be increased [1].

Pharyngeal phase of swallowing usually happens in less than 6 s there by interrupting respiration for only a fraction of usual respiratory cycle. The swallowing centre exclusively inhibits the respiratory centre of the medulla during this time, stopping respiration at any point in its cycle so as to allow swallowing to proceed. Even while a person is talking, swallowing interrupts the respiration for such a short time that is barely perceptible. There is an individual pattern for the swallowing respiration. This gets matured in the teen years and remains consistent thereafter. Peripheral modification by bolus characteristics can also occur. The individual pattern may result in aspiration if disturbed. Injury or disease may also trouble this balance. It can be due to a neurological problem or a common laryngitis [2]. Post-swallow inspiration is more seen in subjects with impaired swallowing. Bolus volume or gender has no effect on the exhale-swallow-exhale pattern [2].

Neural Control of Swallowing

Neural control involves many regions of central nervous system. Similar to all complex motor functions, swallowing is coordinated by a hierarchical sequence of structures in the brain. This ranges from the motor neurons within the motor nuclei of the brainstem up to the cortex [2]. Sensory feedback controls swallowing. Initiation of the act can either be voluntary or reflex due to the stimulation of mucosa in the oral cavity. Saliva accumulation and the presence of food or liquid within the oral cavity also trigger the act.

The neural control of swallowing is done by two major areas of the brain, namely, the cerebral cortex and brainstem. Many cortical areas contribute to voluntary swallowing. Due to close relationship between swallowing and respiration, there is considerable overlap in the brainstem which controls these functions.

The voluntary initiation of swallow happens in bilateral prefrontal, frontal and parietal cortex. Passive initiation of swallow seen in positron emission tomography reveals activity in phase areas of both primary sensory and motor cortex and the prefrontal areas located in front of phase region of the precentral gyrus in primary motor cortex (Brodman's area six). Stimulating these areas results in swallowing activity. Within the cortex, the frontal swallowing centre is organized somatotopically with different areas controlling different swallowing stages.

Studies have shown the oral phase of swallowing is controlled by the lower precentral gyrus and posterior inferior frontal gyrus. More rostromedial region of the cortex within the anterior inferior and middle frontal gyri controls the pharyngeal and esophageal stages [2]. Mostly, the control of swallowing is asymmetrical. The projection from one of the hemispheres is larger, independent of handedness. Other cortical areas involved in the swallowing are the frontal operculum, orbito-frontal cortex and insula. The insula is situated deep to the lateral fissure. It is covered by the opercula of the frontal, parietal and temporal lobes. Disturbances at this level can result in dysphagia. This suggests the cortical swallowing control is hierarchical. Precentral cortex is being influenced by deeper and more caudal centres.

Cortex is important for the voluntary swallowing but not involved in the coordination of swallow. The brainstem areas particularly the medulla are important for the control of swallowing. Descending pathways project to this medullary centre from the frontal swallowing area in the cortex. These are pathways in both the dorsolateral and ventromedial descending systems through the ventral and lateral corticobulbar tracts [2]. In the medulla, there are numerous neurone groups that participate in the control of swallowing. The nuclei which receive afferent input are nucleus tractus solitarius and the spinal trigeminal nucleus [2].

The mouth contains a number of mechanoreceptors which protect the delicate tissues from the high forces during mastication. They help in triggering the reflex, which senses the size and consistency of the food. The efferent pathways from the medulla and pons to the muscles of swallowing involve several cranial motor nuclei. The most important are the nucleus ambiguous for the muscles of the pharynx, the palate and the larynx, the hypoglossal nucleus for the tongue muscles and the motor nuclei of the trigeminal and facial nerves for the muscles of the lips and jaws. The motor neurons within the cervical spinal cord control the muscles of the neck [2].

There are two important groups of neurons involved in the coordination and regulation of swallowing. One group lies in the dorsal of the medulla above the nucleus of the solitary tract, and the other lies ventrally around the nucleus ambiguous. They are the lateral and medial medullary swallowing centres [37]. The dorsal group gets sensory input from various nuclei and is vital in the sequencing of swallowing. The ventral group delivers outputs to the cranial nerve motor nuclei (Figs. 2.9 and 2.10) [38, 39]. The correct sequencing of events for a normal swallow is said to be controlled by a central pattern generator (CPG). This is necessary for the automatic movements such as swallowing, respiration or mastication [40]. In this respect, swallowing is similar to respiration [41].

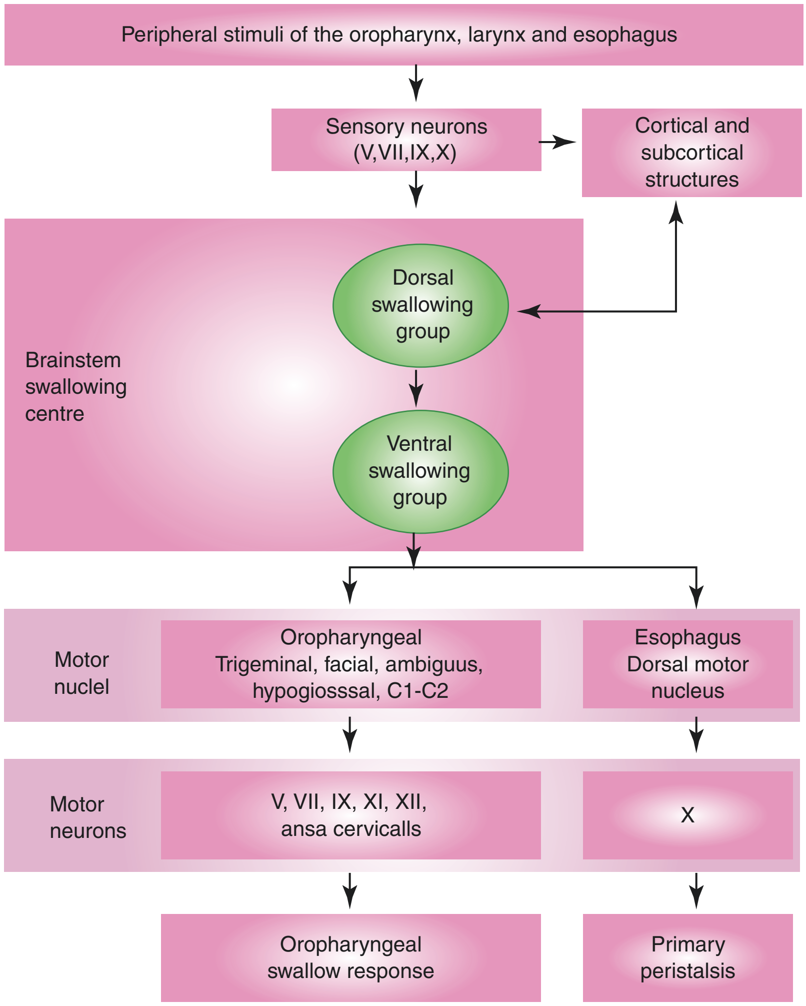

Fig. 2.9 Multidimensional neuronal network of the central nervous system controlling the oropharyngeal swallow response and primary peristalsis [38]

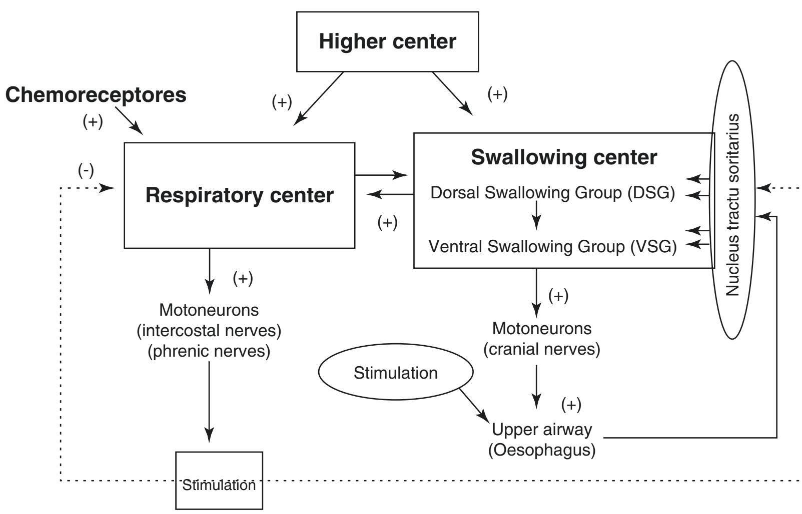

Fig. 2.10 Basis of control of reflex swallowing. The solid line and broken line denote stimulatory and inhibitory pathways

Conclusion

Owing to the complexity of the swallowing process, understanding the normal physiology of eating and swallowing is essential to evaluating and treating dysphagia due to disorders of the head and neck and to developing dysphagia rehabilitation programs. Since the pathways of feeding and breathing share the same anatomical space such the pharynx, the fine temporal coordination of feeding and breathing is essential to provide proper nutrition and to prevent pulmonary aspiration and its sequelae.

The progression of the food bolus through the pharynx is responsible for transit of material into the esophagus and for airway protection. Since the pharynx is converted for only a few seconds at a time into a tract for propulsion of food, it is particularly important that respiration is not compromised because of swallowing. Swallowing can be divided into (1) oral phase, which is voluntary and initiates the swallowing process by moving the food into the posterior part of the oral cavity; (2) pharyngeal phase, which occurs after stimulation of involuntary pharyngeal sensory receptors to elicit the passage of food through the pharynx into the esophagus or the swallowing reflex; and (3) esophageal phase, an involuntary phase that moves the food from the pharynx to the stomach. Moreover, the movement of the food in the oral cavity and to the oropharynx differs between eating solid food and drinking liquid.

Pearls

- Swallowing or deglutition involves the passage of liquid or a bolus of food from the oral cavity to the stomach through the pharynx and esophagus, passing over the entrance to the laryngeal vestibule.
- Swallowing is complex neuromuscular function involving structures in the oral cavity, pharynx, larynx and esophagus, requiring coordinated activity of muscles in these regions.
- Swallowing is a continuous process involving voluntary control and involuntary stages, generally split by convention into three distinct phases: oral, pharyngeal and esophageal.
- Oral, the voluntary phase, is divided into two stages: (1) oral preparatory stage and (2) oral phase proper.
- The oral stage involves tongue muscle actions and mandibular elevation. As the bolus reaches the back of the tongue, soft palate is elevated to protect the nasopharynx from entry of food.
- Pharyngeal phase of the swallowing is physiologically more important because airway protection occurs during this stage.

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