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Anatomy and Physiology of Feeding and Swallowing – Normal and Abnormal

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SYNOPSIS

Eating and swallowing are complex behaviors involving volitional and reflexive activities of more than 30 nerves and muscles. They have two crucial biological features: food passage from the oral cavity to stomach and airway protection. The swallowing process is commonly divided into oral, pharyngeal, and esophageal stages according to the location of the bolus. The movement of the food in the oral cavity and to the oropharynx differs between eating solid food and drinking liquid. Dysphagia can result from a wide variety of functional or structural deficits of the oral cavity, pharynx, larynx or esophagus. The goal of dysphagia rehabilitation is to identify and treat abnormalities of feeding and swallowing while maintaining safe and efficient alimentation and hydration.

Keywords

anatomy; physiology; eating; swallowing; dysphagia

ANATOMY

Anatomy of structures

Understanding the normal physiology and pathophysiology of eating and swallowing is fundamental to evaluating and treating disorders of eating and swallowing, and to developing dysphagia rehabilitation programs. Eating and swallowing are compex behaviors including both volitional and reflexive activities involving more than 30 nerves and muscles.[1]

The Anatomy of the oral cavity, pharynx, larynx and innervations of the muscles are shown in Figure 1 and Table 1. The tongue has both oral and pharyngeal surfaces. The oral cavity is

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separated from the pharynx by the faucial pillars. The pharynx has a layer of constrictor muscles that are originate on the cranium and hyoid bone, and the thyroid cartilage anteriorly, and insert on a posterior median raphe. The submental muscles originate on the mandible and attach to the hyoid bone and tongue. The cricopharyngeus muscle is attached to the sides of the cricoid cartilage anteriorly and closes the upper esophageal sphincter (UES) by compressing it against the back of the cricoid cartilage. The epiglottis originates in the larynx and is angled upward and backward. It is attached to the hyoid bone anteriorly. The space between the pharyngeal surface of the tongue and the epiglottis is called the valleculae. The larynx includes the true and false vocal folds as well as the laryngeal surface of the epiglottis. The laryngeal aditus (upper end of the larynx) opens into the lower portion of the pharynx. Lateral to the larynx are two spaces in the pharynx called the pyriform recesses.

Development of anatomy

The anatomy of the head and neck of the infants is different from the adults. In the infant, teeth are not erupted, the hard palate is flatter, and the larynx and hyoid bone is higher in the neck to the oral cavity. The epiglottis touches the back of the soft palate so that the larynx is open to the nasopharynx, but this airway is separated from the oral cavity by a soft tissue barrier (Fig. 2). However, the anatomy of the pharynx in humans changes with development. As the neck gets longer, the larynx descends to a position lower in the neck. The contact of the soft palate and epiglottis is lost, and the the pharynx becomes longer vertically. This change in human development contributes to the development of speech. However, the pharynx becomes part of both the food way and the airway (Fig. 2). This makes us vulnerable for aspiration.

PHYSIOLOGY

Two paradigmatic models are commonly used to describe the physiology of normal eating and swallowing: the Four Stage Model for drinking and swallowing liquid, and the Process Model for eating and swallowing solid food. The normal swallow in humans was originally described with a three-stage sequential model. The swallowing process was classified into oral, pharyngeal, and esophageal stages according to the location of the bolus.[2, 3] The oral stage was later subdivided into oral preparatory and oral propulsive stages, and the four stage model was established. Studies based on the four stage model adequately describe biomechanics and bolus movement during command swallows of liquids. However, this model cannot represent the bolus movement and the process of eating of solid food. Therefore, the Process Model of Feeding was established to describe the mechanism of eating and swallowing of solid food.[4, 5]

Oral preparatory stage

After liquid is taken into the mouth from a cup or by a straw, the liquid bolus is held in the anterior part of the floor of the mouth or on the tongue surface against the hard palate surrounded by the upper dental arch (upper teeth). The oral cavity is sealed posteriorly by the soft palate and tongue contact to prevent the liquid bolus leaking into the oropharynx before the swallow. There can be leakage of liquid into the pharynx if the seal is imperfect, and this leakage increases with aging.

Oral propulsive stage

During oral propulsive stage, the tongue tip rises, touching the alveolar ridge of the hard palate just behind the upper teeth, while the posterior tongue drops to open the back of the oral cavity. The tongue surface moves upward, gradually expanding the area of tongue-palate contact from anterior to posterior, squeezing the liquid bolus back along the palate and into the pharynx. When drinking liquids, the pharyngeal stage normally begins during oral propulsion.

Oral stage in eating solid food (Process Model of Feeding)

The four stage sequential model has limited utility for describing the process of normal eating in humans, especially food transport and bolus formation in the oropharynx[4-6]. When healthy subjects eat solid food, triturated (chewed and moistened) food commonly passes through the fauces for bolus formation in the oropharynx (including the valleculae) several seconds prior to the pharyngeal stage of a swallow. Additional portions of food can pass into the oropharynx and accumulate there while food remains in the oral cavity and chewing continues. This phenomenon is not consistent with the four stage model, because of the overlap among the oral preparatory, propulsive and pharyngeal stages. The observable events during feeding on solid food are better described with Process Model, which has its origin in studies of mammalian feeding[7] and was later adapted to feeding in humans.[4]

1) Stage I transport—When food is ingested into the mouth, the tongue carries the food to the post-canine region and rotates laterally, placing the food onto the occlusal surface of lower teeth for food processing.

2) Food Processing—Food processing immediately follows stage I transport. During food processing, food particles are reduced in size by mastication and softened by salivation until the food consistency is optimal for swallowing. Chewing continues until all of the food is prepared for swallowing. Cyclic movement of the jaw in processing is tightly coordinated with the movements of the tongue, cheek, soft palate and hyoid bone (Fig. 3).

During drinking of liquid, the posterior oral cavity is sealed by tongue-palate contact during the oral preparatory stage when the bolus is held in the oral cavity. In contrast, during food processing, the tongue and soft palate both move cyclically in association with jaw movement, permitting open communication between the oral cavity and pharynx.[5, 8] Therefore, there is no sealing of the posterior oral cavity during eating. Movements of the jaw and tongue pump air into the nasal cavity through the pharynx, delivering the food's aroma to chemoreceptors in the nose.[9-11]

Cyclical tongue movement during processing is coordinated with jaw movement.[12] Tongue movements during processing are large in both the antero-posterior and vertical dimensions; jaw movements are similarly large in the vertical dimension (Fig. 3A). During jaw opening, the tongue moves forward and downward, reaching its most anterior point in mid- or late jaw opening. It then reverses direction and moves backward in late jaw opening. This prevents us from biting our tongues when we eat. The tongue also moves medioalaterally and rotates on its long (anteroposterior) axis during chewing.[13] These motions are coordinated with cheek movement to keep food on the occlusal surfaces of the lower teeth. The hyoid bone also moves constantly during feeding but its motion is more variable than jaw or tongue movements (Fig 3A and B). The hyoid has mechanical connections to the cranial base, mandible, sternum, and thyroid cartilage via the suprahyoid and infrahyoid muscles. With those muscle connections, the hyoid plays an important role in controlling the movements of the jaw and tongue.

3) Stage II transport—When a portion of the food is suitable for swallowing, it is placed on the tongue surface and propelled back through the fauces to the oropharynx (stage II transport, Fig. 4). The basic mechanism of stage II transport is as described for the oral propulsive stage with a liquid bolus. The anterior tongue surface first contacts the hard palate just behind the upper incisors. The area of tongue-palate contact gradually expands backward, squeezing the triturated food back along the palate to the oropharynx. Stage II transport is primarily driven by the tongue, and does not require gravity.[14, 15] Stage II transport can be interposed into food processing cycles. The transported food accumulates on the pharyngeal surface of the tongue and in the valleculae. If food remains in the oral cavity, chewing continues and the bolus in the oropharynx is enlarged by subsequent stage II transport cycles. The duration of bolus aggregation in the oropharynx ranges from a fraction of a second to about ten seconds in normal individuals eating solid food.[5]

Pharyngeal stage

Pharyngeal swallow is a rapid sequential activity, occurring within a second. It has two crucial biological features: (1) food passage, propelling the food bolus through the pharynx and UES to the esophagus; and (2) airway protection, insulating the larynx and trachea from the pharynx during food passage to prevent the food from entering the airway.

During the pharyngeal stage, the soft palate elevates and contacts the lateral and posterior walls of the pharynx, closing the nasopharynx at about the same time that the bolus head comes into the pharynx (Fig. 5). Soft palate elevation prevents bolus regurgitation into the nasal cavity. The base of the tongue retracts, pushing the bolus against the pharyngeal walls (Fig. 5). The pharyngeal constrictor muscles contract sequentially from the top to the bottom, squeezing the bolus downward. The pharynx also shortens vertically to reduce the volume of the pharyngeal cavity.

Safe bolus passage in the pharynx without aspirating food is critical in human swallowing. There are several airway protective mechanisms preventing aspiration of the foreign materials to the trachea before or during swallowing. The vocal folds close to seal the glottis (space between the vocal folds) and the arytenoids tilt forward to contact the epiglottic base prior to opening of the UES.[16, 17] The hyoid bone and larynx are pulled upward and forward by contraction of the suprahyoid muscles and thyrohyoid muscle. This displacement tucks the larynx under the base of the tongue. The epiglottis tilts backward to seal the laryngeal vestibule. The mechanism of the epiglottic tilting in human swallowing remains unclear, but is probably related to hyo-laryngeal elevation, pharyngeal constriction, bolus movement, and tongue base retraction.[18]

Opening of the upper esophageal sphincter (UES) is essential for the bolus entry into the esophagus. The UES consists of the inferior pharyngeal constrictor muscles, cricopharyngeous muscle and most proximal part of the esophagus. The UES is closed at rest by tonic muscle contraction.[19, 20] Three important factors contribute to the UES opening: 1) Relaxation of the cricopharyngeous muscle; this relaxation normally precedes opening of the UES or arrival of the bolus. 2) Contraction of the suprahyoid muscles and thyrohyoid muscles. These muscles pull the hyo-laryngeal complex forward, opening the sphincter. 3) The pressure of the descending bolus.[21] This pressure distends the UES, assisting its opening. The most important of these mechanisms is #2, the active opening process. This makes opening of the UES quite different from other sphincters (such as the external urethral sphincter that open passively: the urethral sphincter relaxes and is pushed open by the descending fluid bolus.

Esophageal stage

The esophagus is a tubular structure from the lower part of the UES to the lower esophageal sphincter (LES). The lower esophageal sphincter is also tensioned at rest to prevent regurgitation from the stomach. It relaxes during a swallow and allows the bolus passage to the stomach. The cervical esophagus (upper one third) is mainly composed of striated muscle but thoracic esophagus (lower two thirds) is smooth muscle. Bolus transport in the thoracic esophagus is quite different from that of the pharynx, because it is true peristalsis regulated by the autonomic nervous system. Once the food bolus enters the esophagus passing the UES, a peristalsis wave carries the bolus down to stomach through the LES. The peristaltic wave consists of two main parts, an initial wave of relaxation that accommodates the bolus, followed by a wave of contraction that propels it. Gravity assists peristalsis in upright position.

Bolus location at swallow initiation in normal swallows

The position of the head of the bolus relative to the time of pharyngeal swallow onset is a measure of swallow elicitation. The point where the x-ray shadow of the ramus of the mandible crosses the pharyngeal surface of the tongue is commonly used as a marker for this measurement. At one time, it was believed that the pharyngeal swallow was normally triggered when the bolus head passes the fauces as seen on videofluoroscopy.[3] If the bolus head passed the lower border of the mandible more than 1 second before the swallow initiation, it was classified as delayed swallow initiation. Delayed swallow initiation is considered an important finding because the airway is open when the bolus approaches toward the larynx.

However, recent studies have revealed that pre-swallow bolus entry into the pharynx also occurs in healthy individuals drinking liquids.[22-24] Furthermore, as described above, during eating of solid food, chewed bolus is aggregated in the oropharynx or valleculae prior to swallowing. Bolus position at swallow initiation is now known to be quite variable in normal eating and swallowing. This is especially true when consuming a food that has both liquid and solid phases. Saitoh et al. [15] demonstrated that in healthy young adult eating a food that included soft solid and thin liquid components, the leading edge (liquid component) of the food often entered the hypopharynx before swallowing. As seen in Fig. 6, liquid enters the hypopharynx during chewing and approaches the laryngeal aditus at a time when the larynx remains open.

The location of the bolus at swallow initiation is altered by sequential swallowing of liquid.[22, 25-28] The bolus head often reaches the valleculae before pharyngeal swallow initiation, especially when the larynx remains closed between swallows.

Coordination among Eating, Swallowing and Breathing

Eating, swallowing and breathing are tightly coordinated. Swallowing is dominant to respiration in normal individuals.[29-31] Breathing ceases briefly during swallowing, not only because of the physical closure of the airway by elevation of the soft palate and tilting of the epiglottis, but also of neural suppression of respiration in the brainstem.[30] When drinking a liquid bolus, swallowing usually starts during the expiratory phase of breathing. The respiratory pause continues for 0.5 to 1.5 s during swallowing, and respiration usually resumes with expiration.[32-34] This resumption is regarded as one of the mechanisms that prevents inhalation of food remaining in the pharynx after swallowing.[35] When performing sequential swallows while drinking from a cup, respiration can resume with inspiration.[36]

Eating solid food also alters the respiratory rhythm. The rhythm is perturbed with onset of mastication. Respiratory cycle duration decreases during mastication, but with swallowing.[31, 37, 38] The “exhale – swallow – exhale” temporal relationship persists during eating. However, respiratory pauses are longer, often beginning substantially before swallow onset.[11, 38, 39]

ABNORMAL EATING AND SWALLOWING

Dysphagia (abnormal swallowing) can result from a wide variety of diseases and disorders (Table 2).[40, 41] Functional or structural deficits of the oral cavity, pharynx, larynx, esophagus, or esophageal sphincters can cause dysphagia. Dysphagia may lead to serious complications including dehydration, malnutrition, pneumonia, or airway obstruction. In dysphagia rehabilitation, we consider how a given abnormality affects both bolus passage and airway protection.

Structural abnormalities

Structural abnormalities can be congenital or acquired. Cleft lip and palate is one congenital structural abnormality. It hampers labial control for sucking, decreases the oral suction, and causes insufficiency of velopharyngeal closure with nasal regurgitation. Mastication can be impaired by the undergrowth of the maxilla and malalignment of the teeth.

Cervical osteophytes are bony outgrowths from the cervical vertebrae, commonly occurred in the elderly. They may narrow the food path way and direct the bolus toward the airway (Fig. 7).[42] Diverticulae can occur in the pharynx or esophagus. A Zenker diverticulum is a pulsion diverticulum of the hypopharynx that occurs at a weak spot in the muscular wall. Its entrance is located just above the cricopharyngeus muscle, but the body of the pouch can extend much lower.[43] The bolus can enter in the diverticulum and be regurgitated to the pharynx, which may result in coughing or aspiration.

Webs or strictures may occur in the pharynx, esophagus, or sphincters. These can obstruct bolus passage and are usually more symptomatic with solid foods that liquids. A common site for narrowing is the UES. Failure to open the UES may be structural (due to a web or stricture) or functional (due to weakness of the muscles that open the UES).[44] It is difficult to differentiate these conditions, and empirical dilatation is recommended. Stricture is common in the body of the esophagus and is often related to gastroesophageal reflux disease. It is important to consider esophageal carcinoma in the differential diagnosis, since this disease is serious and treatment can improve both survival and quality of life.

Functional abnormality

Impairments affecting the jaw, lips, tongue, or cheek can hamper the oral phase or food processing. Reduced closing pressure of the lips may lead to drooling. Weak contraction of the tongue and soft palate can cause premature leakage of the bolus into the pharynx, especially with liquids. In weakness of the buccal or labial muscles, food can be be trapped in the buccal or labial sulci (between the lower teeth and the cheeks or gums, respectively). Tongue dysfunction produces impaired mastication and bolus formation, and bolus transport. These usually result from tongue weakness or incoordination, but sensory impairments can produce similar effects, including excessive retention of food in the oral cavity after eating and swallowing (Fig. 8).

Loss of teeth reduces masticatory performance. Chewing can be prolonged by missing teeth, and particle size of the triturated bolus becomes larger due to lower efficiency of mastication.[45] Xerostomia hampers food processing, bolus formation and bolus transport during eating. Chemoradiation therapy for head-and-neck cancer often causes delayed swallow initiation, decreased pharyngeal transport, and ineffective laryngeal protection.[46]

Dysfunction of the pharynx can produce impaired swallow initiation, ineffective bolus propulsion, and retention of a portion of the bolus in the pharynx after swallowing. Insufficient velopharyngeal closure may result in nasal regurgitation and reduce pharyngeal pressure in swallow, hampering transport through the UES. Weakness of tongue base retraction or the pharyngeal constrictor muscles can render inadequate the force of pharyngeal propulsion, resulting in retention of all or part of the bolus in the pharynx (usually the valleculae and pyriform sinuses) after swallowing. Incomplete tilting of the epiglottus may obstruct bolus propulsion, especially with higher viscosity boluses, resulting in retention in the valleculae.

Impaired opening of the UES can cause partial or even total obstruction of the foodway with retention in the piriform sinuses and hypopharynx, increasing risk of aspiration after the swallow. Insufficient UES opening can be caused by increased stiffness of the UES, as in fibrosis or inflammation, or failure to relax the sphincter musculature, as noted above.

Weakness of the anterior suprahyoid muscles can impair opening of the UES, since these muscles normally pull the sphincter open during swallowing.

Esophageal dysfunction is common and is often asymptomatic. Esophageal motor disorders include conditions of either hyperactivity (e.g., esophageal spasm), hypoactivity (e.g., weakness), or inccordination of the esophageal musculature. [47] Either of these can lead to ineffective peristalsis with retention of material in the esophagus after swallowing. Retention can result in regurgitation of material from the esophagus back into the pharynx, with risk of aspirating the regurgitated material. Esophageal motor disorders are sometimes provoked by gastroesophageal reflux disease, and in some cases, can respond to treatment with proton pump inhibitors.

Airway protection – penetration/aspiration

Airway protection is critical to swallowing, and its failure can have serious consequences. Laryngeal penetration is defined as passage of the material transported from the mouth or regurgitated from the esophagus enters into the larynx but above the vocal folds. In contrast, aspiration is defined as passage of material through the vocal folds (Fig. 9). Laryngeal penetration is sometimes observed in normal individuals. Aspiration of microscopic quantities also occurs in normal individuals. However, aspiration that is visible on fluoroscopy or endoscopy is pathological, and is associated with increased risk of aspiration pneumonia or airway obstruction.[48] Aspiration can occur before, during or after swallowing. Clinicians should consider the mechanism of aspiration if it is observed on fluoroscopy or endoscopy. Impairments of airway protection can result from reduced hyolaryngeal elevation, impaired epiglottic tilt, incomplete closure of the laryngeal vestibule, or inadequate vocal fold closure due to weakness, paralysis, or anatomical fixation. These impairments can lead to aspiration, usually during the swallow. Aspiration before the swallow is commonly caused by either premature entry of liquids into the pharynx (due to impaired containment in the oral cavity) or by delayed onset of laryngeal closure after a bolus is propelled into the pharynx. Aspiration after the swallow is usually due to accumulated residue in the pharynx after the swallow. Material may be inhaled when breathing resumes after the swallow.

The consequences of aspiration are highly variable, ranging from no discernable effect all the way to airway obstruction or severe aspiration pneumonia. The normal response to aspiration is a strong reflex coughing or throat clearing. However, laryngeal sensation is often abnormal in individuals with severe dysphagia.[49] Silent aspiration, or aspiration in the absence of visible response, has been reported in 25-30% of patients referred for dysphagia evaluations.[49,50,51] Several factors determine the effect of aspiration in a given individual, including the quantity of the aspirate, the depth of the aspiration material in the airway, the physical properties of the aspirate (acidic material is most damaging to the lung, producing chemical pneumonitis), and the individual's pulmonary clearance mechanism.[52] Poor oral hygiene can increase the bacterial load in the aspirate, increasing the risk of bacterial pneumonia.

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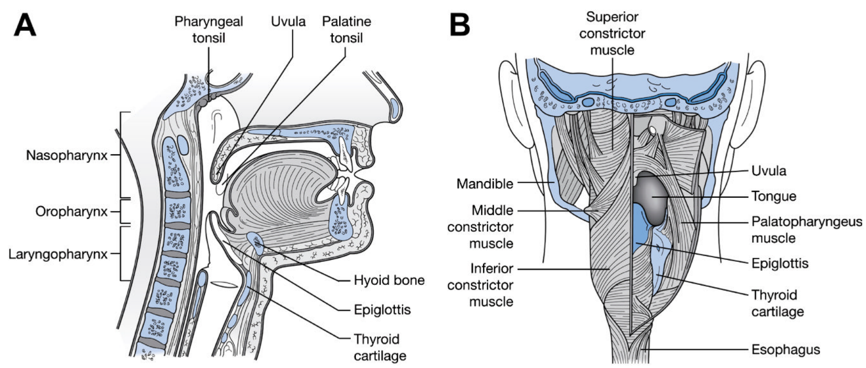

Fig 1. Anatomy lateral view and PA view

Anatomy of the oral cavity and pharynx in (A) the lateral view and (B) posterior view (After Banks et al., 2005, used with permission Two figures from "Atlas of Clinical Gross Anatomy" By Kenneth Moses et al. Elsevier; 2005. ISBN 0323037445 P104, Fig 10.1 Divisions of the pharynx P105, Fig 10.3 Posterior view of the pharynx)

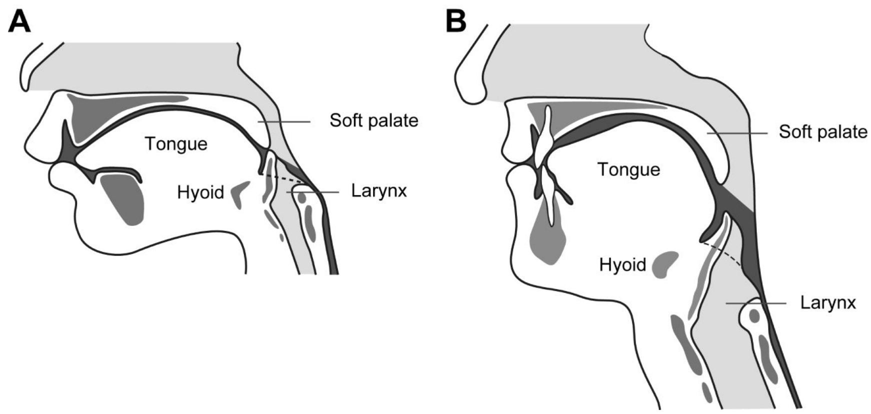

Fig 2. Anatomy of infant and adult

Sagital section of the head and neck in (A) infant and (B) adult human. The food way and the airway are shaded in dark and light grey, respectively. (A) In infant human, the oral cavity is small, the tongue and palate is flatter. The epiglottis is almost attached to the soft palate. The airway and foodway are separated except when swallowing. (B) In adult human, the larynx is lower in the neck, and the food way and airway cross in the pharynx.

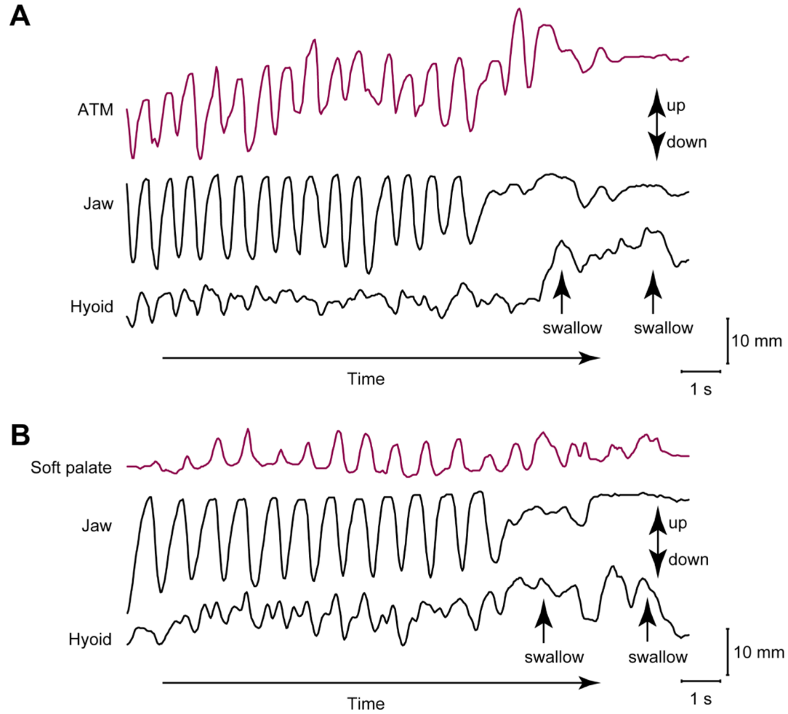

Fig 3. Movements of the jaw, hyoid and tongue (A) or soft palate (B) over time

Movements of the jaw, hyoid and tongue (A) or soft palate (B) over time. Vertical positions of (A) the anterior tongue marker (ATM), lower jaw and hyoid bone and (B) soft palate, lower jaw and hyoid bone, each in a complete feeding sequence. Movement towards the top of the figure is upwards. Positions of the structures are plotted relative to the upper jaw over time. Rhythmic movement of the tongue and soft palate is temporally linked to cyclic jaw movement. The hyoid also moves rhythmically; the amplitude of hyoid motion is greater in swallowing than in processing cycles.

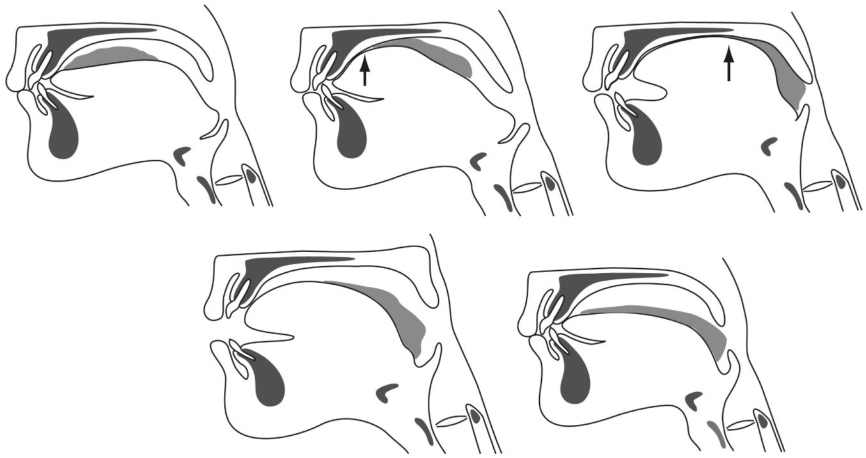

Fig 4. VFG images and drawing of stage II transport

Stage II transport: Drawings based on a videofluorographic recording. The tongue squeezes the bolus backward along the palate, through the fauces, and into the pharynx when the upper and lower teeth are closest together and during early jaw opening phase (first three frames). The bolus head reaches the valleculae while food processing continues (last two frames).

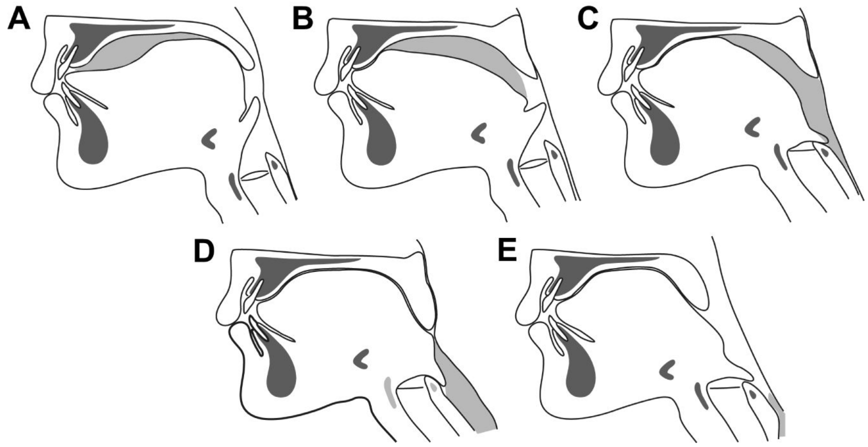

Fig 5. the diagram of swallowing a liquid bolus

Normal swallowing of a liquid bolus: Drawings based on a videofluorographic recording. (A) The bolus is held between the anterior surface of the tongue and hard palate, in a “swallow ready” position (end of **oral preparatory stage**). The tongue presses against the palate both in front of and behind the bolus to prevent spillage. (B) The bolus is propelled from the oral cavity to the pharynx through the fauces (**Oral propulsive stage**). The anterior tongue pushes the bolus against the hard palate just behind the upper incisors while posterior tongue drops away from the palate. (C-D) **Pharyngeal stage**. (C) The soft palate elevates, closing off the nasopharynx. The area of tongue-palate contact spreads posteriorly, squeezing the bolus into the pharynx. The larynx is displaced upward and forward as the epiglottis tilts backward. (D) The upper esophageal sphincter opens. The tongue base retracts to contact the pharyngeal wall, which contracts around the bolus, starting superiorly and then progressing downward toward the esophagus. (E) The soft palate descends and the larynx and pharynx reopen. The upper esophageal sphincter returns to its usual closed state after the bolus passes.

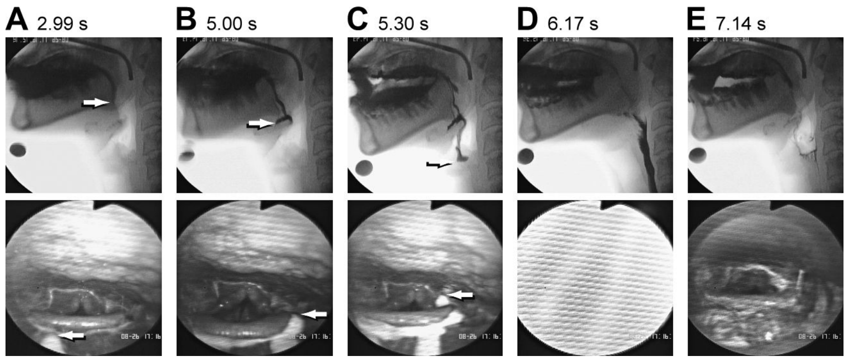

Fig 6. VFG and FEES images of bolus entry in the pharynx with two-phase

Eating food with both liquid and semi-solid phases. Selected images from concurrent videofluorographic and fiberoptic recordings of a normal subject consuming corned beef hash and liquid barium. Numbers above the images indicate the time is seconds from start of the recording. Arrows on the images indicate the leading edge of the barium. The liquid component enters (A) the valleculae, (B) hypopharynx and (C) piriform sinus before (D) swallow initiation while the solid phase is being chewed in the oral cavity. There is no laryngeal penetration or aspiration.

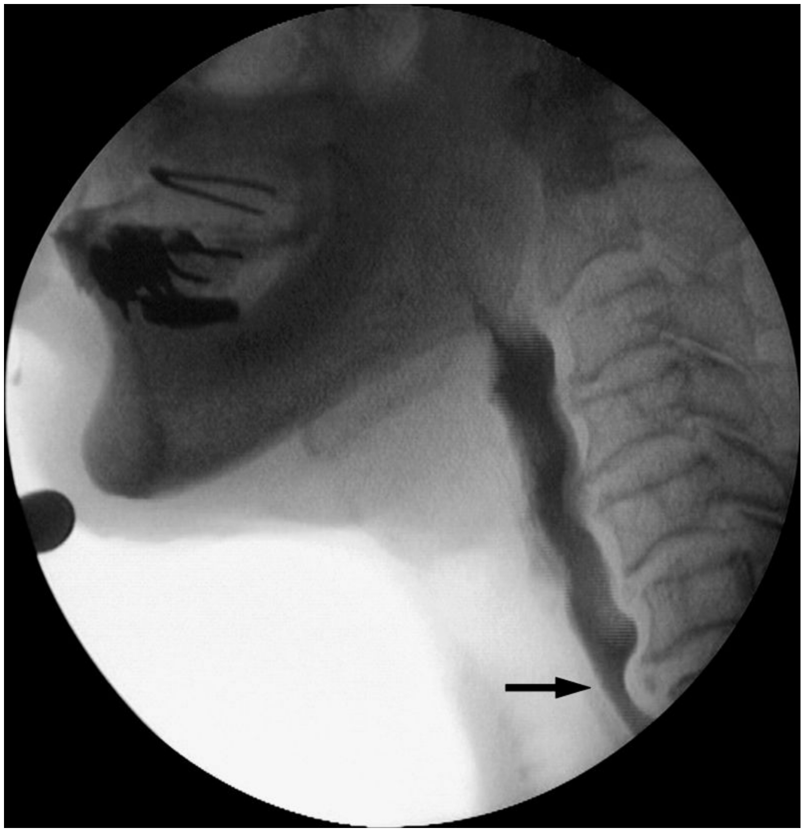

Fig 7. Cervical osteophytes

Partially obstructive C6-7 anterior osteophyte (arrow). It impinges on the column of barium, narrowing the lumen by more than 50%.

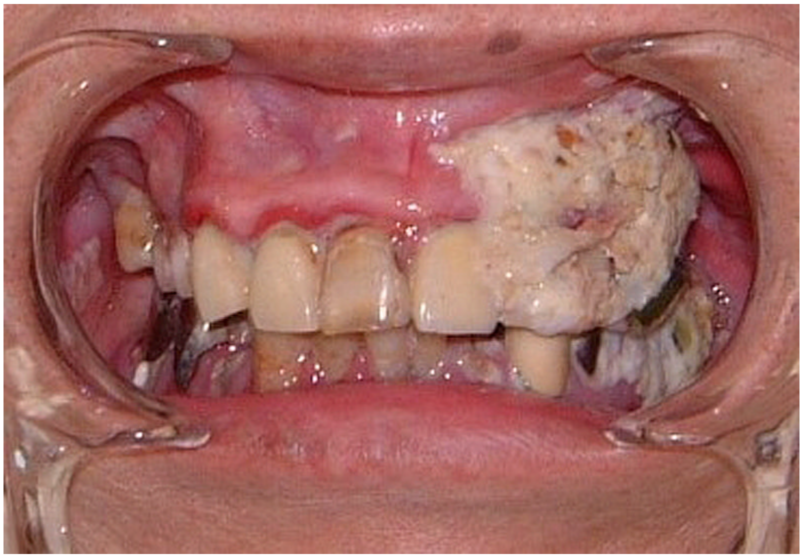

Fig 8. Sensory impairment with impaired function of the buccal muscles

Food debris retained in the left the buccal sulcus in the mouth due to buccal muscle weakness and sensory deficits caused by a right hemisphere stroke.

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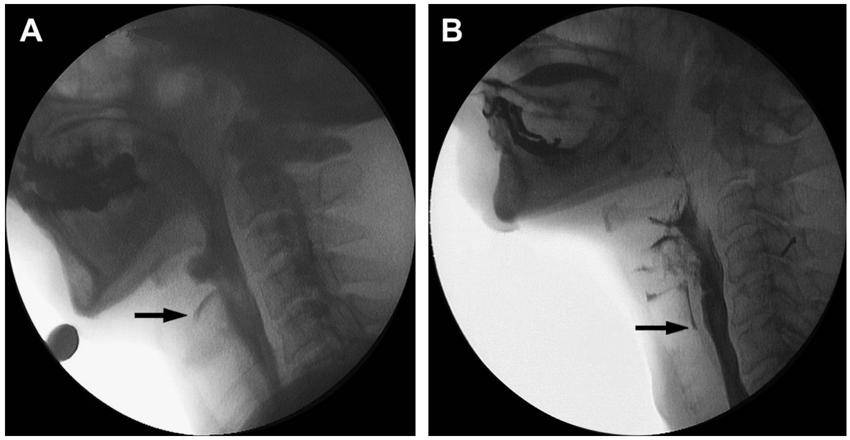

Fig 9. Penetration and Aspiration

Videofluorographic images of laryngeal penetration (A) and aspiration (B) in dysphagic individuals swallowing liquid barium. Arrows indicate the leading edge of the barium in the airway.

Table 1

Innervation of major muscles related to swallowing

Cranial nerves	**Muscles**
Trigeminal Nerve (V)	Masticatory muscles Mylohyoid Tensor veli palatini Anterior belly of digastrics
Facial nerve (VII)	Facial muscle Stylohyoid Posterior belly of digastrics
Glossopharyngeal Nerve (IX)	Stylopharyngeus
Vagus nerve (X)	Levator veli palatine Palatopharyngeous Salpingopharyngeous Intrinsic laryngeal muscles Cricopharyngeus Pharyngeal constrictors
Hypoglossal nerve (XII)	Intrinsic tongue muscles Hyoglossus Geniohyoid Genioglossus Styloglossus Thyrohyoid

Palmer JB, Monahan DM, Matsuo K: Rehabilitation of Patients with Swallowing Disorders. In: Braddom R (Ed): Physical Medicine and Rehabilitation. Philadelphia: Elsevier, 2006, pp. 597-616.

Table 2

Diseases and disorders causing dysphagia

Table 28.2 Selected causes of oral and pharyngeal dysphagia

Neurologic disorder and stroke	**Structural Lesions**	**Psychiatric Disorder**
Cerebral infarction	Thyromegaly	Psychogenic dysphagia
Brain-stem infarction	Cervical hypertosis	
Intracranial hemorrhage	Congenital web	**Connective tissue diseases**
Parkinson's disease	Zenker's diverticulum	Polymyositis
Multiple sclerosis	Ingestion of caustic material	Muscular Dystrophy
Motor neuron disease	Neoplasm	
Poliomyelitis		**Iatrogenic Causes**
Myasthenia gravis		Surgical resection
Dementias		Radiation fibrosis
		Medications

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