Videofluoroscopic Swallowing Studies

A web-based continuing education course prepared by:

Anatomy & Physiology

LENGTH: 30 minutes

OVERVIEW:

The focus of this module is on the anatomy and physiology of swallowing, with the goal of equipping speech-language pathologists with the necessary knowledge to make appropriate referrals for videofluoroscopy.

Learning Objectives

At the end of this module, the clinician learner will:

1) Be able to identify the location and innervation of the sensory receptors that are critical to pharyngeal swallow initiation

2) Be able to identify normal and abnormal respiratory-swallow phasing patterns

3) Be able to describe the components of the brainstem central pattern generator for swallowing

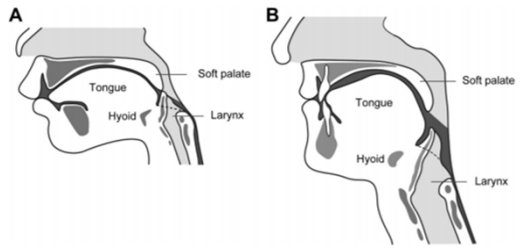
4) Be able to describe the elements of the airway protection mechanism in swallowing

5) Be able to describe the biomechanics of upper esophageal sphincter opening

Overview

- Anatomy of the upper aerodigestive tract
- Review of the aerodigestive tract physiology for:
  - Swallowing
  - Airway protection
  - Swallow-Respiratory coordination

What is different in pediatric anatomy?



Source: Matsuo, K. & Palmer, J. B. (2008). Anatomy and physiology of feeding and swallowing – Normal and Abnormal. Physical Medicine and Rehabilitation Clinics North America, 19(4), 691-707. doi:10/1016/j.pmr.2008.06.001.

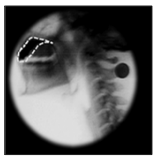
Infant Development

Age (months)	Development/posture	Feeding/oral sensorimotor
Birth to 4–6	Neck and trunk with balanced flexor and extensor tone Visual fixation and tracking Learning to control body against gravity Sitting with support near 6 months Rolling over Brings hands to mouth	Nipple feeding, breast, or bottle Hand on bottle during feeding (2–4 months) Maintains semiflexed posture during feeding Promotion of infant–parent interaction
6–9 (transition feeding)	Sitting independently for short time Self-oral stimulation (mouthing hands and toys) Extended reach with pincer grasp Visual interest in small objects Object permanence Stranger anxiety Crawling on belly, creeping on all fours	Feeding more upright position Spoon feeding for thin, smooth puree Suckle pattern initially Suckle → suck Both hands to hold bottle Finger feeding introduced Vertical munching of easily dissolvable solids Preference for parents to feed
9–12	Pulling to stand Cruising along furniture First steps by 12 months Assisting with spoon; some become independent Refining pincer grasp	Cup drinking Eats lumpy, mashed food Finger feeding for easily dissolvable solids Chewing includes rotary jaw action

Arvedson, J. Swallowing and feeding in infants and young children. GI Motility online (2006) doi:10.1038/gimo17

Swallowing Physiology: A Review

Pre-oral factors



Visual appearance of the bolus
Aroma and smell
Hunger
Motor skills to bring food to mouth
Mealtime environment

Swallowing Physiology: A Review

I. Bolus brought into mouth

- MOTOR FUNCTION:
  - V, XII - bolus positioning for oral processing

Swallowing Physiology: A Review

I. Bolus brought into mouth

- MOTOR FUNCTION:
  - V, XII - bolus positioning for oral processing
- SENSORY FUNCTION:
  - Trigeminal (V) – texture, shape, size, temperature, chemesthesis
  - Facial (VII – Chorda Tympani) – taste (anterior 2/3 of tongue)
  - Glossopharyngeal (IX) – taste (posterior 1/3 of the tongue)
  - Olfactory (I) - aroma

Swallowing Physiology: A Review

II. Oral Processing

- SENSORY FUNCTION:
  - Trigeminal (V) – kinesthesia
- MOTOR FUNCTION:
  - Jaw muscles (V_3) for chewing or stabilization for liquids
  - Buccinator and lip muscles (VII) for bolus containment
  - Palatoglossus (X) for posterior oral cavity seal
  - Tongue muscles (XII)
  - Suprahyoid and laryngeal elevator muscles (V, VII, X, XII)
- SALIVA:
  The salivary glands (VII, IX) contribute towards bolus lubrication

Swallowing Physiology: A Review

III. Oropharyngeal Bolus Transfer

- SENSORY FUNCTION:
  - Trigeminal (V) – kinesthesia
  - Glossopharyngeal (IX) – taste (posterior 1/3 of tongue) and tactile in oropharynx
  - Vagus (X) – tactile in oropharynx

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III. Oropharyngeal Bolus Transfer

- MOTOR FUNCTION:
  - Jaw muscles (V_3) for stabilization
  - Palatal muscles (IX, X) for velar and nasopharyngeal function
  - Tongue muscles (XII)
  - Suprahyoid and laryngeal elevator muscles (V, VII, X, XII)

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IV. Pharyngeal Swallow Initiation

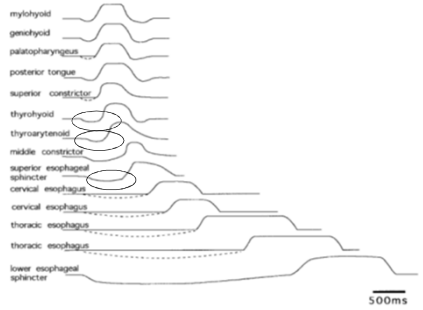
- CENTRAL PATTERN GENERATOR
  - Nucleus Tractus Solitarius, Nucleus Ambiguus, Reticular Formation, related motor nuclei
    - Sensory information reaches threshold for swallowing motor command
    - Respiratory-swallow coordination

Swallowing Physiology: A Review

IV. Pharyngeal Swallow Initiation

- MOTOR FUNCTION:
  - Jaw muscles (V_3) for stabilization
  - Palatal muscles (IX, X) for velar and nasopharyngeal function
  - Tongue muscles (XII)
  - Suprahyoid, laryngeal muscles (V, VII, X, XII) for airway protection
  - Pharyngeal muscles (IX, X) to open UES, shorten pharynx, constrict behind bolus

Sequence of Muscle Contraction



Sequence of muscle contraction in the swallowing leading complex (Doty & Bosma, as cited in Jean, 2001).

UES opening occurs when:

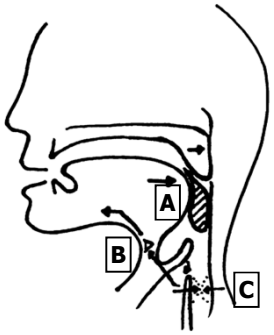
(A) Intrabolus pressure

+

(B) Anterior traction force

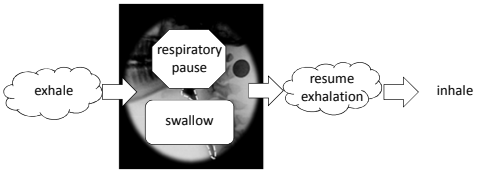
>/=

(C) Resistance at Upper Esophageal Sphincter



Breathing Pattern

- Most common breathing pattern during swallowing:



- Helps prevent aspiration during/after swallow

Swallowing Physiology: A Review

IV. Pharyngeal Swallow Initiation

- MOTOR FUNCTION:
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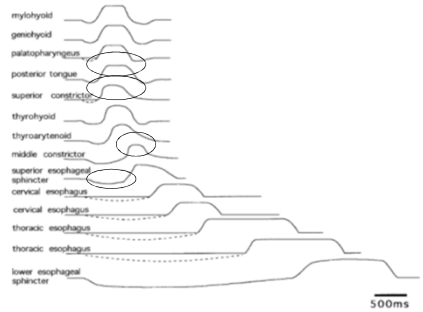
Sequence of Muscle Contraction



Sequence of muscle contraction in the swallowing leading complex (Doty & Bosma, as cited in Jean, 2001).

Swallowing Physiology: A Review

V. After the pharyngeal phase

- Descent of hyoid, larynx and pharynx
- Return of epiglottis to upright
- UES closure behind bolus
- Breathing resumes (typically continued expiration)
- Sensory function important for awareness of penetration-aspiration and residue (and triggering appropriate responses)

Key Messages

- Examination of the patient with dysphagia depends on an in-depth knowledge of normal and abnormal anatomy and physiology of swallowing.
- It is often difficult to tease apart bolus events from physiological or structural movement events.

Key Messages

- Key events in swallowing include:
  - bolus is brought into mouth
  - oral processing
  - oropharyngeal bolus transfer
  - pharyngeal swallow initiation
  - airway protection
  - upper esophageal sphincter opening
  - pharyngeal constriction
  - bolus transfer into the esophagus
  - the esophageal phase

Key Messages

- Airway protection is achieved by way of the following:
  - respiratory pause
  - contraction of the suprahyoid muscles elevating the larynx
  - the arytenoids contact the base of the epiglottis to close the laryngeal vestibule
  - the epiglottis deflects, covering the entrance to the airway

Key Messages

- Infant anatomy differs from adults:
  - key structures are located higher in the pharynx
  - the tongue takes up a larger portion of the oral cavity
  - the epiglottis sits in an intranarial position
- Infant physiology differs from adults:
  - the velum sits in the vallecular space when lowered and the epiglottis remains upright

Key Messages

- Clinical palpation of the hyoid and larynx should not be used to judge the adequacy or distance of movement, but rather simply to confirm that it has occurred.
- It is not possible to evaluate the adequacy of hyolaryngeal excursion and is difficult to confirm the timing or adequacy of UES opening on FEES.

Key Messages

- There is a significantly higher risk of penetration and aspiration associated with:
  - slow closing of the laryngeal vestibule
  - a swallow followed by an inspiratory breath
- Residue may occur due to:
  - inadequate driving forces,
  - poor pharyngeal constriction,
  - inadequate pharyngeal shortening, or
  - incomplete or short UES opening.
- Sensory function is critical to inform the patient of the need for subsequent clearing swallows.

KNOWLEDGE CHECK

1. **The laryngeal surface of the epiglottis houses a dense population of sensory receptors for which nerve, which is critical for pharyngeal swallow initiation?**

   A Recurrent laryngeal nerve

   B Glossopharyngeal nerve

   C Internal branch, Superior laryngeal nerve

   D External branch, Superior laryngeal nerve

2. **True or false? In infants, the soft palate sits in the vallecular space, creating a midline barrier to bolus flow into the pharynx.**

   A True

   B False

3. **True or false? With solids foods that require chewing, it is normal for particles of chewed food to collect in the vallecular space prior to initiation of the pharyngeal swallow.**

   A True

   B False

4. **Which of the following brainstem nuclei is the primary location where sensory signals are processed prior to initiation of a pharyngeal swallow?**

   A Nucleus Ambiguus

   B Nucleus Tractus Solitarius

   C Reticular Formation

   D Hypoglossal nucleus

5. **Which of the following respiratory-swallow coordination patterns is considered normal?**

   A Exhalation – swallow - inhalation

   B Inhalation – swallow - inhalation

   C Inhalation – swallow - exhalation

   D Exhalation – swallow – exhalation

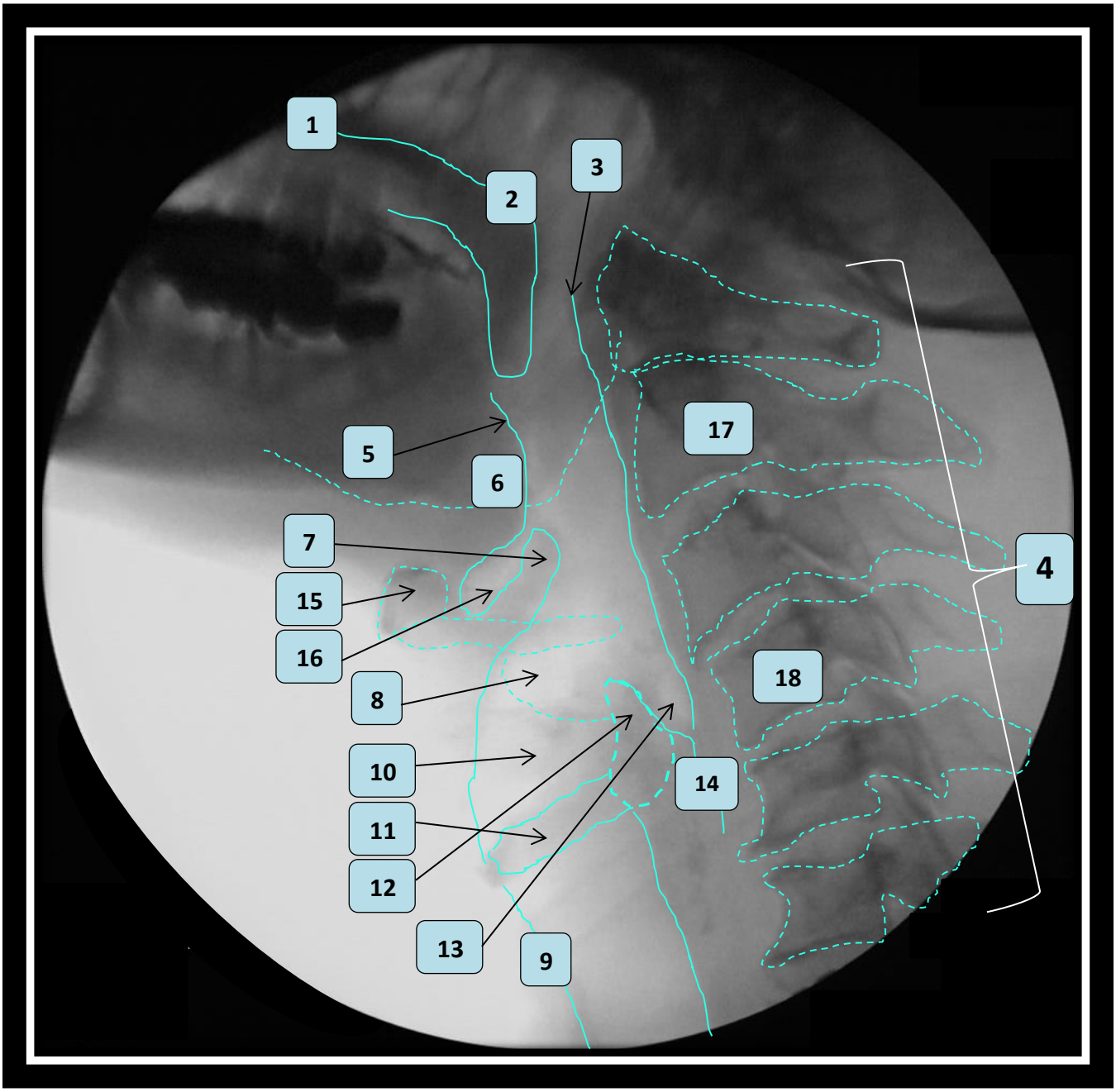
Answer key found on the following page.

KNOWLEDGE CHECK ANSWER KEY

1. C Internal branch, Superior laryngeal nerve
2. A True
3. A True
4. B Nucleus Tractus Solitarius
5. D Exhalation – swallow – exhalation

DIAGRAM LABELLING

Label the following diagram below:



1 Structure: _____, functions as the superior boundary of the _____

2 Structure: _____, functions as the anterior boundary of the _____

3 _____

4 _____

5 _____

6 The point at which the base of tongue intersects with _____

7 _____

8 The entrance to the larynx, or _____

9 The anterior wall of the _____

10 _____

11 _____

12 _____

13 _____

14 _____

15 _____

16 _____

17 Cervical vertebra number: _____

18 Cervical vertebra number: _____

Answer key found on the following page.

DIAGRAM LABELLING ANSWER KEY

1. hard palate / superior boundary of oral cavity
2. soft palate / anterior boundary of nasopharynx
3. posterior pharyngeal wall
4. cervical vertebrae
5. base of tongue
6. base of tongue intersects with ramus of mandible
7. epiglottis
8. entrance to the larynx / laryngeal aditus
9. anterior wall of trachea
10. laryngeal vestibule
11. vocal folds (false, true, laryngeal ventricle)
12. arytenoid process
13. pyriform sinus(es)
14. UES (upper esophageal sphincter) /PES (pharyngo-esophageal segment)
15. hyoid bone
16. valleculae
17. C2
18. C4

EXPAND YOUR KNOWLEDGE

Arvedson, J. (2006) Swallowing and feeding in infants and young children. *GI Motility online.* doi: 10.1038/gimo17

Jean, A. (2001). Brain stem control of swallowing: Neuronal network and cellular mechanisms. *Physiological Reviews, 81*(2), 929-969.

Humbert, I. *The Swallowing Pocket Guide.* Available at www.northernspeech.com

Lang, I. M. (2009). Brain stem control of the phases of swallowing. *Dysphagia, 24*(3), 333-328.

Leonard, R. & Kendall, K. (2018). Dysphagia assessment and treatment planning: A team approach (4th ed.). San Diego, CA: Plural Publishing.

Martin, R. E. (2009). Neuroplasticity and swallowing. *Dysphagia, 24*(2), 218-229.

Matsuo, K. & Palmer, J. B. (2008). Anatomy and physiology of feeding and swallowing – Normal and Abnormal. *Physical Medicine and Rehabilitation Clinics North America, 19*(4), 691-707. doi:10/1016/j.pmr.2008.06.001

Shaker, R. (2013). Manual of diagnostic and therapeutic techniques for disorders of deglutition. New York, NY: Springer.

Steele, C. M. & Miller, A. J. (2010). Sensory input pathways and mechanisms in swallowing: A review. *Dysphagia, 25*(4), 323-333.