Recognizing “Fatigue Effect” and Its Impact on Swallowing in Children

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Normal swallowing requires the coordination of 31 muscles, 6 cranial nerves and multiple levels of the central nervous system, including the brain stem and cerebral cortex.  

_Bosma, 1986_

This sequence (the swallow) seems simple, yet the physiology is so complex that the fact that swallowing succeeds more than it fails...is amazing.  

_J.L. Pitcher_

Research Regarding Physiologic Oral-Motor Fatigue and Reduced Muscular Endurance

- Research has focused primarily on fatigue in adult populations.
- Most studies have focused on the effect of fatigue on speech clarity and swallowing safety.
- Reduced muscular endurance, specifically tongue weakness, has been documented as a factor that can increase aspiration in head and neck cancer patients, as well as in aging and neurologically impaired adults.
Research Regarding Physiologic Oral-Motor Fatigue and Reduced Muscular Endurance

- Robin, DA, Goel, A, Somodi, LB & Luschei ES (1992) showed that maximal strength of the tongue and hand did not differentiate supranormal subjects (trumpet players, debaters) from normal subjects. However, supranormals had significantly longer tongue endurance times that did the normal subjects.
- Solomon, NP, Robin, DA, Mitchinson, SI, VanDaele, DJ & Luschei, ES (1996) concluded that pressures the tongue generated during a constant-effort task declined dramatically after acutely fatiguing the tongue.
- Crow HC & Ship, JA (1996) found that strength in both the tongue and the hand decreased with age, while there was no significant change in tongue and hand endurance with age.

More Research Regarding Physiologic Oral-Motor Fatigue and Reduced Muscular Endurance

- Solomon, NP (2000) found a statistically significant compromising effect of induced tongue fatigue on speech precision in normal adults and an incomplete reversal of this effect after a recovery period.
- Youmans, SR & Stierwalt, JA (2006) found that males had significantly higher maximum isometric pressures than women and that the younger subjects had significantly higher maximum pressures than the older subjects.

And More Research Regarding Physiologic Oral-Motor Fatigue and Reduced Muscular Endurance

- Stierwalt, JA & Youmans, SR (2007) measured tongue strength and endurance using the IOPI in 2 groups of adults, those with normal swallowing and those with impaired swallowing. When matched for age and gender, the impaired group demonstrated significantly lower strength, but not endurance.
- Makashay, MJ, Cannard, KR & Solomon, NP (2015) found that the previous hypothesis that dysarthric speaker are susceptible to speech-related fatigue; instead, speech articulation generally appeared to be resistant to fatigue induced by an hour of moderate functional exercises.
Research Regarding Physiologic Fatigue and Reduced Muscular Endurance during Swallowing

- Logemann, JA, Pauloski, BR, Rademaker, AW, Colangelo, LA, Kahrilas, PJ & Smith, CH (2000) found that there was a reduced muscular reserve in the swallows of older men as compared to younger men. They exhibited longer pharyngeal delays and reduced maximum vertical and anterior hyoid movement as compared to the younger men. They also demonstrated less width of cricopharyngeal opening, indicating less upper esophageal sphincter flexibility during swallows.

More Research Regarding Physiologic Fatigue and Reduced Muscular Endurance during Swallowing

- Kays, SA, Hind, JA, Gangnon, RE & Robbins, J (2010) found that young and old adults demonstrated reduced tongue strength and endurance after dining, but younger subjects showed greater declines in anterior tongue endurance while older adults exhibited signs of swallowing difficulty.
- Namasivayam, AM, Steele, CM & Keller, H (2016) documented that among seniors in long-term care, reduced tongue strength is associated with longer meal times, reduced food consumption, and the presence of observable signs of swallowing difficulty.

Research Regarding Physiologic Oral-Motor Fatigue and Reduced Muscular Endurance in Children

  - DVD group had weaker lingual muscles and significantly reduced tongue strength endurance compared to controls.
Research Regarding Physiologic Fatigue and Reduced Muscular Endurance in Children during Swallowing

• Mizuno, K, Nishida, Y, Taki, M, Hibino, S, Murase, M, Sakurai, M & Itabashi, K (2007) compared infants with BPD and home oxygen therapy, with infants with BPD and no home oxygen therapy, with infants without BPD.
  – Infants with severe BPD exhibited not only poor feeding coordination, but also poor feeding endurance and performance (lowest sucking pressure and frequency, shortest sucking burst duration, lowest frequency of swallows, longest deglutition apnea).
  – BPD babies also had highest respiratory rates and greatest deceases in oxygen saturation.

Research Regarding Physiologic Fatigue and Reduced Muscular Endurance in Children during Swallowing

• Newman, LA, Keckley, C, Petersen, MC & Hamner, A (2001) studied the medical charts of infants referred for VFSS in a university-affiliated medical center.
  – Most infants with suspected dysphagia had very obvious abnormalities (penetration, aspiration, nasal regurgitation).
  – Most did not demonstrate problems in the first few swallows, but difficulties emerged as they continued to feed.
  – Concluded that a) VFSS in infants must examine multiple swallows and b) high incidence of silent aspiration demonstrates the necessity of instrumental assessment to evaluate swallow function.

Clinical signs of dysphagia and fatigue are much more subtle in children than they are in adults.
Causes of Dysphagia in Children

- **Organic**
  - Difficulty swallowing related to actual anatomic, neuromuscular, inflammatory, neoplastic, infection or foreign body associated abnormality.
- **Developmental**
  - Dysfunctional or uncoordinated swallowing the begins early in life and is related to delay of normal feeding and swallowing.
- **Functional**
  - Difficulties in feeding and swallowing that are not due to organic medical problems; conversion, conditioned dysphagia.

Culbert et al, 1996

Populations at Risk for Developing Feeding and Swallowing Disorders

- Neurological problems
- Congenital anomalies
- Cognitive or behavioral limitations
- Metabolic disorders
- Psychosocial problems
- Chronic illness
- GI disorders

Common Symptoms for Referral for Feeding and Swallowing Evaluation

- Difficulties during feeding
- Pulmonary status
- General health/GI issues
- Neurological Problems
- Structural/anatomical differences
Common Symptoms for Referral for Feeding and Swallowing Evaluation

• Difficulties during feeding
  - Weak dysfunctional suck, sucking and swallowing discoordination
  - Breathing disruptions/apnea during feeding
  - Excessive gagging or recurrent coughing/choking during feeding
  - Frequent or copious “spitting up”
  - New onset of feeding difficulty, sudden change in feeding ability
  - Increased congestion/gurgly vocal quality
  - Nasal regurgitation during feeding
  - Watery eyes, grimacing, sneezing, sweating or hiccupping during feeding
  - Irritability or behavior problems during feeding
  - Unexplained food refusal, texture aversion, stress associated with meals
  - Delay in feeding developmental milestones
  - Lack of alertness/change in physiological state during/after feeding
  - Meal times lasting more than 30-40 minutes

Common Symptoms for Referral for Feeding and Swallowing Evaluation

• Pulmonary status
  - Frequent or recurrent pneumonia
  - Recurrent upper respiratory infections
  - Chronic lung changes or infiltrates on chest x-ray
  - Noisy breathing
  - Skin color change

• General health/GI/Digestive issues
  - Frequent low grade fevers
  - Poor weight gain or weight loss for 2-3 months
  - Under-nutrition/failure to thrive
  - Emesis
  - Gastroesophageal reflux (GERD)
  - Constipation

Common Symptoms for Referral for Feeding and Swallowing Evaluation

• Neurological problems
  - Oral-motor discoordination or weakness
  - Reduced oral sensation
  - Dripping persisting beyond age 5 years

• Structural/anatomical differences
  - Craniofacial anomalies
  - Cleft lip/palate
  - Suspected fistula
  - Vocal fold paralysis
Silent aspiration is extremely common in very young children with neuromuscular and other developmental impairments between birth and 5 years of age.

How common?

<table>
<thead>
<tr>
<th>Population</th>
<th>Age Range (years)</th>
<th>% patients with aspiration</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Young peds</td>
<td>0-5</td>
<td>89 -100</td>
</tr>
<tr>
<td>• Older peds &amp; adults</td>
<td>5-55</td>
<td>71 -94</td>
</tr>
<tr>
<td>• Varied</td>
<td>Median 65</td>
<td>51 -58</td>
</tr>
<tr>
<td>• Very old</td>
<td>&gt; 90</td>
<td>73 -88</td>
</tr>
</tbody>
</table>

Lefton-Greif, M, ASHA 2010 presentation

Penetration and Aspiration
Penetration vs Deep Penetration

- Laryngeal penetration – material enters the upper laryngeal inlet, which starts at tip of epiglottis and extends to top of arytenoids.
- Deep laryngeal penetration – material penetrates below level of plane defined by top of the arytenoids to top of the thyroid cartilage, but above true vocal cords; lower 1/3 of laryngeal vestibule.
  - Not uncommon in neurologically normal children, and not a predictor of aspiration in this population (Delzell et al, 1999).
  - Neurologically impaired children who have deep penetration are at risk for aspiration (Friedman & Frazier, 2000).
Landmark for Deep Penetration

Research Regarding Penetration-Aspiration Relationship in Children

- Relationship between depth of penetration and aspiration.
  - 85% children (n = 125, 7 days -19 years) with deep laryngeal penetration also aspirated.
  
  Friedman & Frazier, 2000

- Temporal relationship.
  - Aspiration occurred later than laryngeal penetration on VFSS.
  - 1st penetration = 50.77 sec
  - 1st aspiration = 65.41 sec
  
  Newman et al, 2001

“Fatigue effect” assessment during swallowing is critical.

- Decreased feeding and swallowing efficiency, as seen in neurologically impaired children, can lead to compromised swallowing safety.

- Fatigue typically increases with increased feeding time.

- Some children become more coordinated drinkers/feeders as the VFSS continues (aspirating on only first several swallows).

- Other children demonstrate “fatigue effect”, decreased coordination and efficiency, as well as possibly increased aspiration as VFSS continues.
What signs of swallowing and feeding fatigue have you observed during clinical evaluations with children?

Sucking Patterns of Typical Infants

- Suck: Swallow: Breathe (SSB) is 1:1
- Sucking bursts:
  - Immature: 3-5 sucks/burst
  - Transitional: 5-7 sucks/burst
  - Mature: 10-20 sucks/burst
- Typical feeding pattern includes a suck burst followed by a breathing break, which is essentially a brief period of recovery breathing

Non-Nutritive and Nutritive Sucking

**Non-Nutritive Sucking (NNS)**
- 2/second
- 6-8:1 SSB
- Maintains same number of sucks per burst throughout
- Maintains same duration of breathing breaks throughout

**Nutritive Sucking (NS)**
- 1/second
- 1:1 SSB
- Number of sucks per burst decreases as feeding progresses
- Duration of breathing breaks lengthens as feeding progresses

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Normal Heart Rates

- Newborn = 70 - 190 beats/min (BPM)
- 1-11 months = 80 – 160 BPM
- 1-2 years = 80 – 130 BPM
- 3-4 years = 80 – 120 BPM
- 5-6 years = 75 - 115 BPM
- 7-9 years = 70 – 110 BPM
- 10+ years = 60 – 100 BPM
- Conditioned athletes = 40-60 BPM

- Tachycardia – very increased heart rate, 180 - 280 BPM, up to 300 BPM in infants
- Bradycardia – heart rate in the awake state that is below normal range for age (<100 BPM for infants, <80 for toddlers and young children, <70 for school age children, and <60 for adolescents).

Respiratory Rates

- 0 – 12 months 30-40 bpm
- 1 – 2 years 25-35 bpm
- 2 – 5 years 25-30 bpm
- 5 – 12 years 20-25 bpm
- > 12 years 15-20 bpm

- Tachypnea – increased respiratory rate (>40 bpm in children <2 months of age, >50 bpm in children 2 to 12 months of age, and >80 bpm in children ≥ 1 year of age)
- Bradypnea – abnormally slow breathing (Age 0-1 year < 30 breaths per minute, 1–3 years < 25 bpm, 3–12 years < 20 bpm, 12–50 years < 12 bpm, 50 and up < 13 bpm)

Respiratory & Cardiac Systems

- Difficulties with respiration decrease interest in eating
- Infant must modify respiration to accommodate “work” of eating:
  - Respiratory rate
  - Depth of respiration
  - Heart rate
- Heart rate and efficiency influence the amount of oxygen and carbon dioxide in the blood.
- Cardiac conditions may affect respiratory rate and efficiency, oxygen levels, causing poor circulation and increased respiratory demands for feeding endurance.
Infant-Child Stress Cues

- **State-related**
  - Staring, looking panicked or hyperalert, silent crying, dozing, startle.
- **Motor-related**
  - Facial grimacing, twitching, hyperextension of trunk, neck, arms, legs, head turning, tongue thrusting, squirming, flailing.
- **Autonomic (mild)**
  - Gasp, sigh, sneeze, sweating, hiccup, tremor, startle, strain.
- **Autonomic (severe)**
  - Cough, gag, reflux, skin color change, respiratory pause, irregular respiration, respiratory change.  

Instrumental Assessment by Videofluoroscopic Swallow Study

- Invaluable imaging technique for detailed dynamic assessment of oral, pharyngeal and upper esophageal phases of swallow; best for complete evaluation of pharyngeal phase.
- In infants, the oral and pharyngeal and esophageal swallow phases are so closely related, often oral phase dysphagia is accompanied by pharyngeal and/or esophageal dysphagia.
- **Goal:** Obtain maximum information in minimal amount of time.

Radiation Safety During VFSS

- X-rays = radiant energy that enters matter.
- Some x-rays are absorbed by and interact with matter partially or completely, while others pass through without interaction.
- When x-rays enter the body, denser tissues (teeth and bone) absorb more x-rays than softer tissue (muscles and digestive organs).
- Human tissue has variable sensitivity to radiation.
- Younger, rapidly developing tissue is more sensitive to the effects of radiation than older tissue.
Rules of Reason Regarding Radiation Safety

- Rule 1 – medical necessity; how important is specific information required from imaging procedure?
- Rule 2 – principle of keeping exposure levels “as low as reasonably achievable” (ALARA) (Tolbert, 1996).
  - Minimize x-ray dose by:
    - a) *Keeping exposure times as short as possible*.
    - b) Carefully “panning in” to visualize only area being examined.
    - c) Shielding reproductive organs of patient.
    - d) Reducing number of radiographs/fluoroscopic exams administered.

Radiation Safety/VFSS Exposure Times

- Acquire maximum information in a minimal amount of time.
  - No more than 5 minutes of radiation exposure with adults.
  - No more than 2-3 minutes of radiation exposure with older children.
  - Most studies with infants can be completed in 60-90 seconds (Arvedson & Brodsky, 2000).
- Mean duration of radiation exposure during VFSS exams:
  - Mean Duration (minutes) – 2.48 +/- 0.81
  - Range of Duration (minutes) – 0.05 to 8.12
  
Assessing for “fatigue effect” could prolong videofluoroscopic swallowing studies and increase radiation exposure to the sensitive rapidly developing tissues of children.

How do we assess for “fatigue effect” during a VFSS without compromising safety?
Assess for “Fatigue Effect”

• Allow child to continue to feed on food/liquid without barium; turn fluoroscopy equipment off for 5-10 minutes; observe swallowing again with fluoroscopy on with barium-mixed foods/liquids.
  – Recommend have doubles of cups and bottles for easy switch between liquids with and without barium.

• Finish the VFSS by returning to initial consistencies (often liquids) after all other food and liquid presentations are complete, for swallowing safety and efficiency comparison.

• Evaluate what happens if oral and pharyngeal residuals are difficult to clear due to fatigue; monitor them as they thin with saliva.

Instrumental swallowing evaluation reports should always include comments regarding the presence of “fatigue effect”.

• Describe the signs of fatigue and consequences, such as
  – Increased difficulties initiating swallows
  – Increased labial spillage
  – Increased respiratory rate or breathing coordination difficulty
  – Increased swallow response delays with premature spillage to the pyriform sinuses
  – Decreased oral efficiency, prolonged mastication, oral holding
  – Penetration or aspiration
  – Increased oral and/or pharyngeal residuals
  – Increased agitation or other state changes
  – Others?
Documenting “Fatigue Effect”

- Recommend ways to successfully decrease or avoid fatigue, such as
  - Initiating limited oral intake trials while continuing to provide supplemental nutrition and hydration
  - Slowly increasing intake amounts while monitoring stamina and digestive tolerance
  - Pacing
  - Schedule shorter, more frequent meals and snacks
  - Positioning (more support, side-lying, slight recline, etc)
  - Modifying bottle nipple so that less effort is needed to feed
  - Modifying diets to include less difficult to manage foods and liquids
  - Working with a nutritionist to increase the caloric content of foods
  - Others?

If you, the primary SLP and referring therapist, suspect fatigue or have other special requests of the speech-language pathologist conducting the instrumental swallowing evaluation, PLEASE SPEAK UP!

Communication and collaboration will ALWAYS yield the best results for our youngest clients!
Clear communication and collaboration between speech-language pathologists working with very young children and their families in outpatient, school and home settings could decrease the need for repeated instrumental assessments, as well as facilitate modification of therapeutic activities and caregiving routines to ensure improved health and treatment outcomes.

Flexibility

Thank you!

Questions? Ideas?!?

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References

• Benfer KA, Weir KA, Bell KL, Ware RS, Davies PSW & Boyd RN. Oropharyngeal dysphagia and gross motor skills in children with cerebral palsy. Pediatrics 2013; 131: e1553-e1562.
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