Rehabilitative Interventions for Neurogenic Dysphagia

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Outline

– Introductions
– Principles of rehabilitation and neuroplasticity
– Swallowing pathophysiology review (VFSS examples)
  • Why are penetration and aspiration happening?
  • Why does post-swell residue happen?
– Mapping from pathophysiology to treatment: indications and outcome measures
– Case studies:
  • Tongue-pressure training
  • Effortful Swallow & Mendelsohn Maneuver
  • Shaker Exercise

What is dysphagia?

• A major syndrome, that can occur at anytime across the lifespan, and may be characterized by any of the following:
  – Difficulty swallowing
  – Impaired ability to protect the airway during swallowing (penetration-aspiration)
  – Impaired ability to transport food or liquid efficiently through the throat (prolonged eating, residues)
• These difficulties may contribute to:
  – Risk of respiratory difficulties (pneumonia)
  – Risk of dehydration and/or malnutrition
  – Restriction in social eating activities
  – Reduced quality of life related to eating and drinking.

Swallowing integrity involves:

• Sensory-motor coordination in the brainstem
• Sequenced muscle contraction
• Structural movement (Biomechanics)
• Coordination, intricate timing relationships
• Sensory feedback
### PE Segment opening

opening occurs when:

(A) Bolus driving forces  
(B) Hyolaryngeal anterior traction force  
(C) Resistance at PE Segment

\[ (A) + (B) \geq (C) \]

### Goals of Intervention

**Compensation**
- To achieve an immediate, but temporary improvement in function
- Analogy: a crutch

**Rehabilitation**
- To achieve a durable change in physiology and function
- Relies on “plasticity” (central, peripheral)
Key Principles of Plasticity
1. Use it or lose it
2. Use it and improve it
3. Repetition matters
4. Time matters
5. Intensity matters
6. Specificity matters
7. Salience matters
8. Difficulty matters
9. Transference
10. Interference
11. (Age matters)

Kleim & Jones, JSLHR, 2008

Strength training

Applying principles of exercise physiology in swallowing rehabilitation
- Targeting particular muscles
- Considerations of load, intensity, dose response

Structural Changes with Strength Training:
- Peripheral Adaptation:
  - Fibre type shifts from fast fatigue Type I fibres to slow contracting, fatigue resistant Type II
  - Muscle hypertrophy with increased force generation capacity
- CNS Change:
  - Cortical reorganization
  - Decreased motor thresholds with training
  - Increased cortical map area with skill training
Use it or lose it

• If a neural substrate is not biologically active, its function can degrade
  – Disuse leads to:
    • Weakening of synapses of neglected function
    • Strengthening of synapses involved in more consistent behaviours
  – Do any of our treatments promote disuse?
  – How can we promote use?

Intensity Matters

• The “Overload Principle”
  – Skeletal muscle does not adapt unless it is forced beyond the “typical” range of activity
• Intensity is sometimes referred to as “Mechanical Load”

Burkhead, Sapienza & Rosenbek (2007)

“Skill”-based training

Three vital components of skill-based motor training:

• Specificity of practice:
  – the activity must be directly relevant to the desired motor task
• Challenge:
  – the task should continue to challenge the patient
• Feedback:
  – patients should be provided with feedback about their performance


Biofeedback

• Real-time biofeedback (commonly via sEMG) enables monitoring of one’s own intrinsic bodily functions and facilitates improvement of behaviour through enhanced voluntary motor control
Use it and improve it

- “Use” is not enough!
- We must consider WHAT and HOW we are using and engaging the system to maximize functional outcomes.

Task Specificity Matters

Although repetition matters, we should consider WHAT is being repeated and aim to enhance the accuracy/quality/coordination/strength of the affected system.

Difficulty Matters

Carefully select treatment targets that
- Are achievable for the patient
- Challenge the patient
- Involve a progression of difficulty
  - Load (strength targets)
  - Longer practice (strength, endurance)
  - Skill (timing, coordination)
  - More challenging boluses

Repetition Matters

- Neural substrates
  - May be modified by extensive & prolonged practice
  - May not become consolidated until later in the training process
- In the therapy setting, this typically translates to:
  - Number of repetitions
  - Number of treatment sessions
  - Treatment duration
What does this look like in dysphagia rehabilitation?

• Thicker liquids enhance the safety of swallowing and reduce the incidence of pneumonia.
• More research is needed to determine the benefit of high intensity swallowing therapy... at improving swallowing ability and return to a normal diet.
• It is unclear whether transcutaneous electrical stimulation improves swallowing function.
• Variations of head positioning may be beneficial for improving swallowing function however, further research is required.
• There is conflicting evidence regarding the effect of thermal application on swallowing function and complications in patients with dysphagia.
• Transcranial direct current stimulation and repetitive transcranial magnetic stimulation may improve dysphagia outcomes, however additional research trials are necessary.

Recommended Reading

  – Part I – Background and methodology.
  – Part II – Impact of dysphagia treatment on normal swallow function.
  – Part III – Impact of dysphagia treatments on populations with neurological disorders.
  – Part IV – Impact of dysphagia treatment on individuals post cancer treatments.
  – Part V – Applications for clinicians and researchers.

8-point Penetration Aspiration Scale (Rosenbek et al., 1996)

| NORMAL | 1 | Material does not enter the airway |
| 2 | Material enters the supraglottic space but is ejected |
| PENETRATION | 3 | Material enters the supraglottic space but is NOT ejected |
| 4 | Material contacts the true vocal folds but is ejected |
| 5 | Material contacts the true vocal folds but is NOT ejected |
| ASPIRATION | 6 | Material passes below the true vocal folds but is ejected to the supraglottic space |
| 7 | Material passes below the true vocal folds but is NOT ejected despite patient attempts to clear |
| 8 | Material passes below the true vocal folds but there is no patient response |

Steele. ICCD 2017. Do not distribute without permission.
Penetration-Aspiration Rating

- Which anatomical boundaries REALLY matter?
- What is the clinical significance of residue remaining in the supraglottic space?
- Most studies to date collapse the P-A scale, either into a binary scale (1 vs. 2-8, or 1-2 vs. 3-8) or a 3-way scale (1 vs. 2-5 vs. 6-8)
- Remember that the scale is CATEGORICAL (so reporting average P-A scale scores for a group has no interpretable meaning)

Determining the Mechanisms behind Swallowing Impairment

- Parameters related to impaired safety
- What is normal?
  - Laryngeal vestibule closure
  - Swallow response time
  - Hyoid excursion
  - Residue

Laryngeal Vestibule Closure

- What do you need to measure this:
  1. Find the frame of LVC
     - i.e., the frame when the arytenoids reach their highest position, ideally contacting the undersurface of the epiglottis
  2. Determine whether or not there is complete closure
     - IF yes, within normal limits ✓
     - IF no, LVC is impaired ❌

Physiological Factors Related to Aspiration Risk: A Systematic Review
Carlo M. Steele and Julie A. Y. Cicero
Received: 18 October 2013/Accepted: 23 January 2014
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http://rd.springer.com/article/10.1007%2Fs00455-014-9516-y

- Old age
- Risk is not constant from swallow to swallow
- Risk is not constant across different bolus consistencies
- Reduced tongue strength
- Respiratory rate > 25 bpm
- Non exp-ap-exp pattern
- ? Hyoid excursion (needs to be confirmed using anatomically normalized measures)
- ? Time to laryngeal vestibule closure/bolus dwell time
Swallow Response Time

- What do you need to measure this:
  1. Find the frame of bolus entering the pharynx
     - i.e., the frame when the bolus crosses the shadow of the ramus of mandible
  2. Find the first frame of the hyoid “burst” (a rapid anterior-superior movement of the hyoid)
  3. Figure out how long the interval is:
     - IF < 500 ms for a sip of < 16 ml WNL [i.e. 16 frames at 30/s]
     - IF > 500 ms, swallow response time is a concern

Laryngeal Vestibule Closure Reaction Time

The interval between the frames of:
- Onset of Hyoid Burst
- Maximum Laryngeal Vestibule Approximation

95% CI: 65-137 ms
(i.e., 2 to 4 frames @ 30/s)

Measuring hyoid excursion...
Reference Distance:

\[ xy \geq 1.5 \times y \]

**Maximum XY Hyoid Position**

Bolus volume (ml)
Maximum Hyoid Excursion

- What do you need to measure this:
  1. Find the frame of maximum excursion
     - i.e., the frame when the hyoid reaches the furthest forward position at maximum elevation
  2. Use the length of the C2-4 spine as a reference
  3. Determine whether hyoid distance from C4 is ≥ 1.5 times the length of the C2-4 spine scalar
     - IF yes, within normal limits ✓
     - IF no, hyoid excursion is reduced ×

Issues in residue rating...

- WHERE do you measure?
  - Valleculeae, pyriform sinuses, pharyngeal walls, UES?
- WHEN do you measure?
  - After 1st, 2nd, terminal swallow for a bolus?
- Is residue judged relative to the bolus or to the space available in the pharynx?
- How much residue is “too much” residue?

MBSImp

Scored for “Oral residue” and “Pharyngeal residue”
Judged after completion of the FIRST swallow for all boluses (except with sequential swallowing where the measure is made after the last swallow in the sequence)

0 – none
1 – “trace” involving an outline of coated structures
2 – “collection” more than trace, an amount of the original bolus remaining that is sufficient to “scoop”
3 – “majority” > 50% of the original bolus is remaining
4 – minimal to no clearance of the original bolus

“Eisenhuber Scale”

(15-ml high-density 250% w/v barium; scored after first swallow)

0 – no residue
1 – “mild” i.e., 0-25% full (versus height of the space)
2 – “moderate”, i.e., 25-50% full
3 – “severe”, i.e., > 50% full

The Normalized Residue Ratio Scale (NRSS)  
(Pearson, Molfenter, Smith & Steele, 2012)
- Calculated using *ImageJ* analysis software
- Measures residue area in pixels and area of the space in pixels (valleculae or pyriform sinuses)
- Adjusts for differences in size using a cervical spine scalar

\[
NRSS = \frac{A_1}{(A_1 + A_2)} \times \frac{(A_1/N)^2 \times 10}{(A_1/N)^2 \times 10}
\]

How much residue is “too much”?

- For thin liquid barium (20% w/v):
  - Valleculae: > 26% full / NRSSv > 0.07
  - Pyriform Sinuses: > 19% full / NRSSp > 0.2

Steele et al., 2015. ESSD presentation.

Why do you think residue happens?
Mechanisms Involves in Postdeglutition Retention in the Elderly

- Low tongue driving force (diffuse; valleculae)
- Reduced pharyngeal shortening (diffuse; pyriforms)
- Reduced pharyngeal constriction (diffuse)
- To date, tongue-pressure resistance training has not yielded significant improvement of residue
- Some reports suggest effortful swallow may be effective

Determining the Mechanisms behind Swallowing Impairment

- Parameters related to impaired efficiency
- What is normal?
  - Pharyngeal constriction
  - UES opening

Pharyngeal Constriction

Pharyngeal Area at Maximum Constriction

Stokely et al, 2015
Pharyngeal Constriction

• What do you need to measure this:
  1. Find the frame of maximum pharyngeal constriction
     • TIP: this will appear as closure of the pharyngeal lumen BEHIND the bolus tail
  2. Determine if there is complete closure or not?
     • < 5% of C2-4 reference space filled with air or bolus
     • IF yes, within normal limits ☑
     • IF no, pharyngeal constriction is impaired ☒

Case Studies in Rehabilitation:

1) Tongue-pressure resistance training
2) Effortful Swallow and Mendelsohn Maneuver
3) Shaker Exercise

Iowa Oral Performance Instrument (IOPI)
www.iopimedical.com

• Records pressure when tongue compresses air-filled bulb against the palate
• Pressure displayed on screen in kiloPascals
• 1 kiloPascal = 7.5 mm Hg

SwallowSTRONG Device
(formerly known as the Madison Oral Strengthening Tool or MOST®)
www.swallowsolutions.com
Tongue strength treatment protocol (Robbins)

- 3 sessions per day; 3 nonconsecutive days of the week (e.g., Mon, Wed, Fri)
- 1 set of 10 repetitions (presses) per session using the anterior and posterior tongue (6 sets per day in total)
- Exercise targets:
  - Beginning week 1: 60% of baseline max
  - Beginning week 2: 80% of baseline max
  - End week 2: recalculate max; 80% new max
  - End week 4: recalculate max; 80% new max
  - End week 6: recalculate max; 80% new max
  - End week 8: recalculate max (outcome measure)

Norms for Tongue-Palate Pressures in KPa
(Fei et al., 2013, *Dysphagia*, DOI 10.1007/s00455-013-9469-6)

<table>
<thead>
<tr>
<th>Task</th>
<th>Females</th>
<th>Males</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age</td>
<td>95% confidence interval</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>Lower (boundary)</td>
</tr>
<tr>
<td>Maximum Isometric Pressures</td>
<td>&lt; 40</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>&gt; 60</td>
<td>41</td>
</tr>
<tr>
<td>Saliva swallows</td>
<td>&lt; 40</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>&gt; 60</td>
<td>15</td>
</tr>
<tr>
<td>Water swallows</td>
<td>&lt; 40</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>&gt; 60</td>
<td>11</td>
</tr>
</tbody>
</table>

The Effects of Lingual Exercise on Swallowing in Older Adults
JoAnne Robbins, PhD, Ronald E. Gangnon, PhD, Shannon M. Theis, MS, Stephanie A. Kays, MS, Angela L. Hewitt, MS, and Jacqueline A. Hind, MS

JAGS 53:1483-1489, 2005
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ORIGINAL ARTICLE

The Effects of Lingual Exercise in Stroke Patients With Dysphagia
JoAnne Robbins, PhD, Stephanie A. Kays, MS, Ronald E. Gangnon, PhD, Jacqueline A. Hind, MS, Angela L. Hewitt, MS, Luizell R. Gentry, MD, Andrew J. Taylor, MD

Anterior: 46% increase vs. baseline; Posterior: 81% increase vs. baseline.

- **N** = 56 veterans (1 female) with heterogeneous diagnoses VFSS confirmed dysphagia (PAS>2; residue)
- Significant increases in tongue strength during first 4 weeks, continued improvement to 8 weeks
- Improved FOIS scores, SWAL-QOL, decreased swallowing effort
- NO differences in aspiration or residue scores
- Decreased hospitalization rates after treatment; trend towards reduced pneumonia over 6 months (but not significant)

Other exercise targets might be considered:

- Neuromuscular Treatments for Speech and Swallowing: A Tutorial
  - Heather M. Clark
  - Appalachian State University, Boone, NC
  - AJSLP, 12, 400-415 (2003).
What other kinds of exercise targets might be considered?

<table>
<thead>
<tr>
<th>TABLE 2 (p. 1 of 3)</th>
<th>Treatment strategies, therapeutic mechanisms, and predicted applications to the speech and swallowing systems.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Neuromuscular Impairment or Function Targeted</strong></td>
<td><strong>Therapeutic Mechanism</strong></td>
</tr>
<tr>
<td>Strength training</td>
<td>Weakness</td>
</tr>
<tr>
<td>Strength</td>
<td>Ability to produce large forces in short bursts (Type II motor units)</td>
</tr>
</tbody>
</table>

https://www.researchgate.net/profile/Catriona_Steele2/publications
Case Study

- 70 year old woman
- 96 days post Left frontal parietal ischemic CVA;
- Prior right frontal ischemic CVA with no residual dysphagia
- Right facial weakness
- Significant dysarthria
- Anterior MIP: 18 kPa
- Posterior MIP: 16 kPa

Protocol for Case Study

- An intensive course of tongue-pressure resistance training emphasizing improved strength and control of pressure timing
- 60 tongue-palate presses per session including maximum posterior isometric pressures, saliva swallows and effortful saliva swallows (ALL with slow release) plus a generalization task with nectar-thick liquids (slow release)
- Biofeedback from Iowa Oral Performance Instrument
Tongue Pressure Resistance Training?
- It is worth knowing if your patient has reduced tongue strength (MIP < 40 kPa)
- Tongue strength CAN improve with 6-8 weeks of exercise (ideally with biofeedback)
- Aspiration may improve (particularly if related to poor liquid bolus control?)
- Residues may, or may not, improve

Effortful Swallow
- Available data primarily only report on immediate compensatory effect of the effortful swallow:
  - Improved clearance (less vallecular and pyriform sinus residue) and improved hyolaryngeal excursion with this manoeuvre (but in healthy adults!?)

Tongue Pressure Resistance Training?

Effortful Swallow

- Pharyngeal pressure benefits (both amplitude and timing) of effortful swallow are enhanced when pressure emphasis is located between tongue and palate (rather than in pharynx while de-emphasizing tongue-palate pressure)

Case Study
- 82 year old male
- 3 months post lateral medullary stroke
- Previously no coordinated pharyngeal swallow
  - Limited LVC
  - Limited pharyngeal constriction
  - Limited UES opening
  - Significant pyriform sinus residue
  - Aspiration of residue

Steele. ICCD 2017. Do not distribute without permission.
What we decided to do:

- 8 weeks of twice-per-week therapy using effortful swallow
- sEMG for biofeedback
  - Saliva swallows
  - 5 Regular effort swallow amplitudes measured at the beginning of each session
  - 55 repetitions of 110-120% of regular effort amplitude

Mendelsohn Maneuver


- original paper, showing link between laryngeal elevation and PE segment opening
- maximizing hyolaryngeal elevation augments size of PE segment opening
- prolonging hyolaryngeal elevation increases duration of PE segment opening

Questions regarding the Mendelsohn Maneuver

- The manoeuvre is difficult to teach
- Even using sEMG biofeedback, it is possible to create the signal picture that we believe represents a “correct” MM using different strategies

Case Study

- 25-year old female
- Severe dysphagia due to lupus-related vasculitis
- Previously lacking a coordinated pharyngeal swallow
  - Absent hyo-laryngeal excursion
  - Limited pharyngeal constriction
  - Limited UES opening
  - Significant pyriform sinus residue
**What we decided to do:**

- 8 weeks of twice-per-week therapy using Mendelsohn Maneuver
- sEMG for biofeedback
  - Emphasis on sustaining amplitude > 30% of regular effort saliva swallows for 2-3 seconds
  - 60 repetitions per session

**Mendelsohn Maneuver?**

- Definitely worth trying in patients with incomplete or short LVC
- Definitely worth trying in patients with restricted UES opening
- Consider using sEMG biofeedback paired with vigilant clinical observation
- Be aware that the manoeuvre can be done incorrectly and lead to maladaptation
- Not recommended if you cannot monitor outcome using VFSS

**Shaker Exercise**


- An **isometric-isokinetic** head lifting exercise used for treating swallowing difficulties caused by reduced opening of the upper esophageal sphincter (UES).
- In particular, it aims to improve the strength of the suprahyoid muscles (mylohyoid, geniohyoid, digastric) which contribute to opening the UES via traction.

**Shaker Exercise**

- Patient lies in the supine position (without a pillow) and performs 3 sustained head raisings for 1 minute. The head must be raised high and forward enough to see the toes without raising their shoulders off the bed/floor. Each lift is interrupted by a 1-minute rest period (Shaker et al., 2002).
Shaker Exercise

- Following the sustained head raisings, short lifts are repeated 30 times (Shaker et al., 2002).

Muscles contributing to hyoid excursion

Contraction of supraphyoid musculature moves the hyoid superiorly (mylohyoid) and anteriorly (geniohyoid).

Evidence regarding the Shaker Exercise


Shaker Exercise – Latest Evidence

A Randomized Study Comparing the Shaker Exercise with Traditional Therapy: A Preliminary Study

- 19 participants with 3 month history of dysphagia and impaired UES opening on videofluoroscopy
- Randomized to “traditional therapy” or Shaker exercise for 6 weeks
- 14 participants underwent pre- and post-treatment VFSS
Shaker Exercise – Net Evidence

- Decrease in post-swallow aspiration (but no accompanying change in post-swallow pharyngeal residue, although measures were extremely blunt, i.e. present/absent)
- Queried impact on actual range of hyoid excursion* or laryngeal excursion (mixed results across studies, when reported in mm in either the anterior or superior direction)
- Reported increases in UES opening diameter and accompanying decrease in intra-bolus pressure, suggesting easier passage of the bolus through the UES
- Functional outcomes appear to be dependent on compliance with the exercise beyond 2 weeks
- Different muscles respond over course of treatment: SCM first and supra/infra hyoids responding only after extended practice VFSS

Variations on the Shaker

- Submental sEMG activity measured during both CTAR and Shaker task in 40 healthy adults
- Similar profiles of muscle activity, but significantly increased amplitude in the CTAR tasks

Follow up study (2016)

- Similar activation and fatigue of suprahypoid muscles in both exercises
- CTAR involves less activation of sternocleidomastoid
• Maximum jaw opening, hold for 10 seconds
• N = 8 patients with chronic dysphagia (heterogeneous etiologies); UES opening < 10 mm on 5 ml nectar-thick bolus
• 5 repetitions, 2 sets X 4 weeks

<table>
<thead>
<tr>
<th>Measure</th>
<th>Before Mean ± SD</th>
<th>Before Lower</th>
<th>Before Upper</th>
<th>After Mean ± SD</th>
<th>After Lower</th>
<th>After Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upward movement of the hyoid bone (mm)</td>
<td>6.05±1.16</td>
<td>2.37</td>
<td>9.52</td>
<td>10.60±4.52</td>
<td>6.83</td>
<td>14.38</td>
</tr>
<tr>
<td>Forward movement of the hyoid bone (mm)</td>
<td>7.17±2.46</td>
<td>2.46</td>
<td>11.30</td>
<td>9.83±6.64</td>
<td>6.64</td>
<td>12.26</td>
</tr>
<tr>
<td>UES opening width (mm)</td>
<td>6.10±2.39</td>
<td>2.47</td>
<td>8.16</td>
<td>7.27±7.69</td>
<td>4.09</td>
<td>9.59</td>
</tr>
<tr>
<td>Time for pharynge passage (s)</td>
<td>0.98±0.09</td>
<td>0.90</td>
<td>1.05</td>
<td>0.75±0.33</td>
<td>0.47</td>
<td>1.02</td>
</tr>
</tbody>
</table>

What we decided to do

• 8 week home program of Shaker exercise 3 times daily

Shaker Exercise

• Definitely worth trying if your patient has reduced UES opening leading to residue and post-swallow aspiration
• We need to measure change in residue with a more informative scale (new NRRS scale)
• ? Need to develop graded challenge
• Can the same exercise effects be achieved without lying down (towel-tuck)?
• Are there specific aspects of task performance that might alter results (jaw clench during?)
• As a first step prior to botox or myotomy?
Treatments to consider to address mechanisms of aspiration

- **TONGUE**
  - Tongue pressure resistance training; Effortful swallow
- **LARYNGEAL VESTIBULE CLOSURE**
  - Chin down; Texture modifications
- **RESPIRATORY-SWALLOW CO-ORDINATION**
  - 3-second oral hold; Supraglottic swallow; EMST
- **HYO-LARYNGEAL EXCURSION**
  - Effortful swallow; Mendelsohn maneuver; Shaker

Treatments to consider to address mechanisms of residue

- **TONGUE**
  - Tongue pressure resistance training; Effortful swallow
- **HYO-LARYNGEAL EXCURSION**
  - Effortful swallow; Mendelsohn maneuver; Shaker
- **UES OPENING**
  - Mendelsohn maneuver; Shaker

Key Principles of Plasticity

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QUESTIONS?