How to Integrate Cough Evaluation and Cough Skill Training into Dysphagia Management

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Disclosures

• James Borders
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• Katya Villareal
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• Michelle Troche
  Salary: Teachers College, Columbia University
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  Royalties: MedBridge Inc
  ASHA registration waiver: ASHA
Research aimed at improving health outcomes and quality of life associated with disorders of swallowing, cough, and speech production.
Learning Objectives

• Describe the theoretical underpinnings and rationale for cough as an important airway protective behavior

• Provide practical approaches to evaluate sensory and motor aspects of cough in clinical practice

• Illustrate the clinical implementation evaluation and treatment of cough skill training in case presentations
Have you or someone (SLP) you know ever....

• Asked a patient to cough during a cranial nerve exam.
• Made an assumption based on a cough (or absence of cough) on a clinical swallowing evaluation.
• Used the penetration-aspiration scale.
• Prescribed a ‘cough’ during meals or after liquids.
Why do we care about these things?
We care about whether our patient can protect their airway

<table>
<thead>
<tr>
<th>PAS Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Material does not enter the airway</td>
</tr>
<tr>
<td>2</td>
<td>Material enters the airway, remains above the vocal folds, and is ejected from the airway</td>
</tr>
<tr>
<td>3</td>
<td>Material enters the airway, remains above the vocal folds, and is not ejected from the airway</td>
</tr>
<tr>
<td>4</td>
<td>Material enters the airway, contacts the vocal folds, and is ejected from the airway</td>
</tr>
<tr>
<td>5</td>
<td>Material enters the airway, contacts the vocal folds, and is not ejected from the airway</td>
</tr>
<tr>
<td>6</td>
<td>Material enters the airway, passes below the vocal folds, and is ejected into the larynx or out of the airway</td>
</tr>
<tr>
<td>7</td>
<td>Material enters the airway, passes below the vocal folds, and is not ejected from the trachea despite effort</td>
</tr>
<tr>
<td>8</td>
<td>Material enters the airway, passes below the vocal folds, and no effort is made to eject</td>
</tr>
</tbody>
</table>
Without knowing we KNOW that swallowing and cough disorders co-exist

Reflex Cough and Disease Duration as Predictors of Swallowing Dysfunction in Parkinson’s Disease

Michelle S. Troche1 · Beate Schumann2 · Alexandra E. Brandimore1

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Voluntary Cough Testing as a Clinical Indicator of Air in Cervical Spinal Cord Injury

Laura Pitts, PhD, CCC-SLP BCS-S; Valerie K. Hamilton, MS, CCC-SLP; Erii Stephanie Watts, PhD, CCC-SLP; Leora R. Cherney, PhD, CCC-SLP

Voluntary Cough and Clinical Swallow Function in with Spastic Cerebral Palsy and Healthy Controls

Avinash Mishra1 · Georgia A. Malandraki2 · Justine J. Sheppard3 · Andrew Michelle S. Troche2

Sensorimotor Cough Dysfunction Is Prevalent and Pervasive in Progressive Supranuclear Palsy

James C. Borders, MS, CCC-SLP1,2 · Jordanna S. Sevitz, MS, CCC-SLP1 · James A. Curtis, PhD, CCC-SLP, BCS-S,1 · Nora Vanegas-Arroyave, MD,3 and Michelle S. Troche, PhD, CCC-SLP1

DOI 10.1007/s00455-015-9871-1

Voluntary Cough Airflow Differentiates Safe Versus Unsafe Swallowing in Amyotrophic Lateral Sclerosis

Emily K. Plowman1,2 · Stephanie A. Watts3,4 · Rael Robison1,2 · Lauren Tabor1,2 · Charles Dion3 · Joy Gazzino4 · Tuan Vu5 · Clifton Gooch6

Cough Strength and Expiratory Force in Aspirating and Nonaspirating Postradiation Head and Neck Cancer Survivors

Katherine A. Hutcheson, PhD; Martha P. Barrow, MPH; Carla L. Warneke, MS; Yiqun Wang, MA; George Eapen, MD; Stephen Y. Lai, MD, PhD; Denise A. Barringer, MS; Emily K. Plowman, PhD; Jan S. Lewin, PhD

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And we know that (an effective) cough is good for clearing the airway - and important for preventing aspiration pneumonia.
So if we know all of this....
How can we do better?

• Many clinicians who treat individuals with dysphagia report limited education related to cough
• Over 97% SLPs in a recent survey reported an interest in learning more about cough assessment.

A Survey of Speech-Language Pathologists’ Experience With Clinical Cough Assessment

Michela Jean Mir\textsuperscript{a,b,\textdagger} and Karen Wheeler Hegland\textsuperscript{b}

\textsuperscript{a} Rehabilitation Science PhD, College of Public Health and Health Professions, University of Florida, Gainesville \textsuperscript{b} Department of Speech, Language, and Hearing Sciences, University of Florida, Gainesville
Let the Cough 101 course begin....
Airway Protection: A Continuum of Behaviors

Swallowing  Glottal stop/ LAR  Exp reflex  Exp effort  Throat clear  Cough

Prevention  Ejection

(Troche, Brandimore, Godoy, & Hegland, 2014)
A Framework to Understand Airway Protection

Concrete and abstract signaling systems:
- Sensory Nuclei
- Somatosensation
- Motor Nuclei
- Swallow CPG
- Cough CPG
- Resp CPG

Urge-to-Act:
- Volitional Control

Afferents

(Efferents)

(Troche, Brandimore, Godoy, & Hegland, 2014)
Cough is....

• A mechanism of airway protection
• A sensorimotor behavior which serves to protect the pulmonary system by generating expiratory airflows that create ‘scrubbing’ action, removing material from the airway
• Forced expiratory maneuver, usually against a closed glottis, associated with a characteristic sound

In order to generate high airflow velocities during cough you need four things:
• Inspiration
• Adduction of vocal folds/closure of the laryngeal vestibule
• Rapid opening of the vocal folds and larynx
• Forced expiration
Types of cough (and their unique importance)

Cough

Voluntary Cough

Reflex Cough
How might DYSTUSSIA manifest in my patients?
Dystussia is....

• Disordered or pathologic cough
• Related terms
  • Eutussia – Normal cough
  • Hypertussia – Too much cough
  • Hypotussia – Too little cough
  • Atussia – absent cough
How does DYStussia manifest in people with dysphagia?

- Higher cough thresholds
- Blunted urge-to-cough
- Disorganized/reduced voluntary control of cough
- Reduced peripheral strength
- Increased variability in cough performance

Figure from Armstrong & Okun 2020

Framework from: Troche et al, 2014
Dysphagia and Dystussia commonly (always?) co-exists!
Cough Evaluation: A Step-by-Step Tutorial

Gold Standard
- Spirometry +/- Tussigenic Stimuli

Clinical Implementation
- Handheld Peak Flow Meters
- Handheld Nebulizers
- Auditory-Perceptual
Spirometry: the Gold Standard

Equipment

• Pneumotachograph coupled with a facemask
  • Connected to a computer to visualize airflow during breathing and coughing

Pneumotachograph  Facemask  Filter  Full setup
Cough Measurement with Spirometry

What can PEFR predict?
Swallowing safety deficits in people with dysphagia
• PEFR < 5.24 L/s had 100% specificity to detect aspiration on instrumental swallowing evaluation (Pitts et al., 2010)

Ability to clear the airway on an instrumental swallowing evaluation
• PEFR of 5 L/s predicted 80% of aspiration expelled from subglottis (Borders et al., 2021)

Cough Inspired Volume (CIV)
Amount of air inspired before coughing

Compression Phase Duration (CPD)
Time from end of inspiration to beginning of expiratory phase

Peak Expiratory Flow Rate (PEFR)
Peak airflow during the expiratory phase of the cough
Cough Measurement

Cough Inspired Volume (CIV)
Amount of air inspired before coughing

Compression Phase Duration (CPD)
Time from end of inspiration to beginning of expiratory phase

Peak Expiratory Flow Rate (PEFR)
Peak airflow during the expiratory phase of the cough

Please rate your urge-to-cough

<table>
<thead>
<tr>
<th>Rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>None at all</td>
</tr>
<tr>
<td>1</td>
<td>Very slight</td>
</tr>
<tr>
<td>2</td>
<td>Slight</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
</tr>
<tr>
<td>4</td>
<td>Somewhat severe</td>
</tr>
<tr>
<td>5</td>
<td>Severe (heavy)</td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Very, very severe</td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Very, very, very severe</td>
</tr>
<tr>
<td></td>
<td>(almost maximal)</td>
</tr>
</tbody>
</table>
Voluntary Cough Testing

Step-by-Step Guide

• Hold the facemask tightly against face
• Provide instructions with a model
  “Cough hard one time”
• Maintain tight seal with facemask during coughing
• Hold in place for 1 - 2 seconds after coughing
• Remove facemask
Spirometry

Instructions

• Single Voluntary Cough
  • Elicits one strong cough
  • Ideal for clearing material from the *upper* airway
  • Can be a stronger cough than sequential

“Cough hard one time”
Voluntary Cough Testing: Interpretation

Single

Peak Flow: 1.12 L/s

Cough Inspired Volume: -0.10 L

Cough Expired Volume: 0.16 L

Compression Phase Duration: 0.45 s

Clinical Takeaways

High likelihood of airway invasion on instrumental swallowing evaluation

Poor airway clearance of aspiration

Pitts et al. (2010); Borders & Troche (2021)
Spirometry

Instructions

• Sequential Voluntary Cough
  • Imitates cough response to aspiration
  • Elicits multiple coughs
  • Clear material from the lower airway

“Cough like something went down the wrong tube”

Hegland et al. (2014)
Moving onto... Reflex Cough Testing

Delivery of sensory stimulus on inhalation + Continuous delivery of sensory stimulus

Nebulizer + Dosimeter + Nebulizer

e.g., Miles et al. (2013)
• Protocol improves predictive value of swallowing screens and reduces pneumonia and mortality rates.

Considerations
• Unable to randomize dosages
• Difficult to assess urge-to-cough
# Reflex Cough Testing

<table>
<thead>
<tr>
<th></th>
<th>Capsaicin</th>
<th>Citric Acid</th>
<th>Distilled Water</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensory receptors</strong></td>
<td>Stimulates airway receptors that mediate coughing to prolonged irritation</td>
<td>Stimulates laryngeal receptors involved in coughing to aspiration</td>
<td>Poorly defined</td>
</tr>
<tr>
<td><strong>Reproducibility after repeated exposure</strong></td>
<td>Good</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Clinical implementation</strong></td>
<td>Difficult</td>
<td>Easy</td>
<td>Easiest</td>
</tr>
<tr>
<td><strong>Potential adverse effects</strong></td>
<td>Allergy</td>
<td>Tachyphylaxis</td>
<td>Bronchoconstriction</td>
</tr>
</tbody>
</table>

*References: Wallace et al. (2019, 2022); Ohno et al. (2022); Hegland et al. (2016); Mazzone et al. (2011); Dicpinigaitis & Alva (2005)*
Reflex Cough Testing

Step-by-Step Guide

• Confirm no allergy to capsaicin

• Randomize order of different amounts of capsaicin
  • 0 μM, 50 μM, 100 μM, 200 μM
Reflex Cough Testing

Step-by-Step Guide

- Hold the facemask tightly against face

- Provide instructions

- Hold facemask in place after presentation of stimulus and remove facemask

- Wait at least 30 seconds if no immediate cough response

- Ask to rate urge-to-cough and take a sip of water

"Relax with the facemask in place and cough if you need to"

<table>
<thead>
<tr>
<th>Please rate your urge-to-cough</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
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<tr>
<td>5</td>
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<tr>
<td>6</td>
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<tr>
<td>7</td>
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<tr>
<td>8</td>
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<tr>
<td>9</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
Reflex Cough Testing: Interpretation

200µM Capsaicin

Produced 5 reflexive coughs with a peak flow of 2.85 L/s

Clinical Takeaways
Adequate cough response to capsaicin
Urge-to-cough rating of 9
Reduced cough strength
Reflex Cough Testing: Interpretation

200µM Capsaicin

No reflexive cough response to a high dose of capsaicin

Clinical Takeaways

No cough motor response to high dose of capsaicin
Urge-to-cough rating was low

May indicate inability to detect and cough in response to airway invasion
Spirometry: the Gold Standard

Benefits
• High precision and validity
• Measure timing, volume, and strength of cough

Drawbacks
• High cost
• Lack of portability
What can I use to evaluate cough today?
Handheld Devices

Voluntary Cough Testing

**Sequential**

“Cough like something went down the wrong tube”

**Single**

“Cough hard one time”

**Analog**

- Number of coughs
- Cough strength

**Digital**

- Number of coughs
- Cough strength
- Cough expired volume

Silverman et al. (2014); Tabor-Gray et al. (2019)
## Handheld Devices
### Voluntary Cough Testing

<table>
<thead>
<tr>
<th>Device</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
</table>
| Analog   | • Affordable (~ $20)  
• Multi-use with filter and facemask                            | • Only measures cough strength            |
| Digital  | • Monitors adherence  
• Measures CEV  
• Multi-use with filter and facemask                            | • Expensive ($50)  
• Requires software program                                      |

**Sequential**

“Cough like something went down the wrong tube”

**Single**

“Cough hard one time”
Handheld Devices

Reflex Cough Testing

• Handheld nebulizer
  • Measures presence and number of coughs to sensory stimulus
  • Affordable (~ $30)

Instructions

“Relax with the device in your mouth. Cough if you need to.”

• Keep device in place for 1 minute or until patient produces two coughs.
• Rate urge-to-cough

Hegland et al., 2016
Handheld Devices

Reflex Cough Testing
• Handheld nebulizer

Clinical Takeaways
• Absent motor response to sensory stimuli
• No urge-to-cough

Hegland et al., 2016
Handheld Devices

Reflex Cough Testing

- Handheld nebulizer

Setup with Handheld Peak Flow

- Connect handheld peak flow meter with a t-tube to facemask and handheld nebulizer
- Allows for additional measurement of cough strength

Curtis et al. (2020)
Auditory-Perceptual Cough Assessment

• Most SLPs include auditory-perceptual assessments of cough in clinical swallowing evaluations

• Emerging evidence...
  • Raters can be reliable with training
  • Unknown validity
    • Some evidence that perceptual characteristics are associated with objective cough outcomes

Table 1: Definitions of Cough Descriptors

<table>
<thead>
<tr>
<th>Descriptors</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Quality</strong></td>
<td></td>
</tr>
<tr>
<td>Strength</td>
<td>Perceived force and loudness of expired airflow, taking into consideration distance from the sound source</td>
</tr>
<tr>
<td>Crispness</td>
<td>Perception of an abrupt (as opposed to gradual) and distinct pop of expired airflow at the onset of the expulsive cough phase</td>
</tr>
<tr>
<td>Voicing</td>
<td>Perception of vocal fold vibration during the expulsive cough phase</td>
</tr>
<tr>
<td>Strain</td>
<td>Perception of excessive vocal effort (hyperfunction), when voicing is present</td>
</tr>
<tr>
<td>Duration</td>
<td>Length of time of the expiratory phase of cough</td>
</tr>
<tr>
<td>Effectiveness</td>
<td>Perceived effectiveness at clearing material from the airway</td>
</tr>
<tr>
<td>Normality</td>
<td>How normal (as opposed to abnormal) the expiratory maneuver sounds</td>
</tr>
<tr>
<td>Coordination</td>
<td>How coordinated (as opposed to discoordinated) the expiratory maneuver sounds</td>
</tr>
</tbody>
</table>

Curtis et al. (2023); Laciuga et al. (2016)
Auditory-Perceptual Cough Assessment

- Number and type of coughs
  - Cough
  - Throat clear
  - Huff

- Quality of the cough
  - Crispness

Rated from 0-100

- Normal
- Mild-to-Moderate
- Severe

Curtis et al. (2023)
Auditory-Perceptual Cough Assessment

• Number and type of coughs
  • Cough
  • Throat clear
  • Huff

• Quality of the cough
  • Crispness
  • Duration

Rated from 0-100

  Short
  Long
Rehabilitating Airway Protection

Urge-to-Act

Somatosensation

Volitional Control

Sensory Nuclei

Resp CPG

Swallow CPG

Cough CPG

Motor Nuclei

Efferents

(Afferents

(Troche, Brandimore, Godoy, & Hegland, 2014)
A Framework to Understand Airway Protection

- Sensory Nuclei
  - Somatosensation
  - Afferents
  - Sensory Nuclei
- Volitional Control
- Urge-to-Act
- BCA
- Motor Nuclei
- Cough CPG
- Swallow CPG
- Efferents

(Troche, Brandimore, Godoy, & Hegland, 2014)
People with dysphagia can up-regulate voluntary and reflex cough function despite a blunted perception of cough-inducing stimuli (Brandimore et al., 2017; Hegland et al., 2012; Troche et al., 2014)
Treatments: Sensorimotor Training for Airway Protection (smTAP)

Sensorimotor Skill-based Paradigm

Key features:

- Salient **context** for cough execution
  - Emphasis on **urge-to-cough**
- Salient **verbal cue**: “**cough hard**”
- Salient **visual cues** for cough airflow:
  - Target set at 25% above baseline cough PEFR
  - Real-time biofeedback of cough PEFR

(brandimore et al., 2017; hegland et al., 2012; troche et al., 2014; troche et al., 2022)
Home Training Program:
Sensorimotor Training in Airway Protection (smTAP)

Day 1: 1 hour
Day 2: 25 coughs
Day 3: 25 coughs
Day 4: 25 coughs
Day 5: 25 coughs

x 5 weeks
Rehabilitating Cough Dysfunction in Parkinson’s Disease: A Randomized Controlled Trial

Michelle S. Troche, PhD, CCC-SLP, James A. Curtis, PhD, CCC-SLP, Jordanna S. Sevitz, MS, CCC-SLP, Avery E. Dakin, MS, CCC-SLP, Sarah E. Perry, PhD, CCC-SLP, James C. Borders, MS, CCC-SLP, Alessandro A. Grande, MPhil, Yuhan Mou, MA, CCC-SLP, Nora Vanegas-Arroyave, MD, and Karen W. Hegland, PhD, CCC-SLP

(Troche et al., 2022)
Results: Participants

There were no adverse events reported throughout the study (Troche et al., 2022; Doruk et al., 2023)
Results: Delayed Baseline

Peak Expiratory Flow Rate (Voluntary Cough PEFR)
• Voluntary cough PEFR decreased between baseline 1 and the 5-week delayed baseline, by an average of 0.09 L/s or ~3% of baseline PEFR ($p < .001$) when controlling for the number of coughs.

Maximum Expiratory Pressure (MEP)
• No significant main effect of time.
## Results: Summary of treatment findings

<table>
<thead>
<tr>
<th>OUTCOME</th>
<th>EMST</th>
<th>smTAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penetration-Aspiration Score</td>
<td>Improved</td>
<td>Improved</td>
</tr>
<tr>
<td>MEP</td>
<td>Improved by 22 cm H2O*</td>
<td>Improved by 8 cm H2O</td>
</tr>
<tr>
<td>Voluntary Cough PEFR</td>
<td>Improved by 0.17 L/s</td>
<td>Improved by 0.51 L/s</td>
</tr>
<tr>
<td>Reflex Cough PEFR</td>
<td>Decreased by 0.23 L/s</td>
<td>Improved by 0.53 L/s</td>
</tr>
<tr>
<td>Urge-to-Cough</td>
<td>No change</td>
<td>Improved</td>
</tr>
<tr>
<td>FOIS</td>
<td>No change</td>
<td>No change</td>
</tr>
<tr>
<td>SWAL-QOL</td>
<td>No change</td>
<td>No change</td>
</tr>
</tbody>
</table>

- Confirmed the **efficacy of smTAP** for the improvement of both motor AND sensory aspects of voluntary and reflex cough function, above and beyond the changes seen with EMST, the current gold standard for airway protection treatment in PD.
Discussion: Clinical Significance

- Changes in cough effectiveness are of clinical significance for airway protection

- **Voluntary** PEFR for participants with severe DIGEST safety profiles went from 2.83 (SD = 0.81) to 3.36 (SD = 1.06)

- **Reflex** PEFR for participants with severe DIGEST safety profiles went from 2.60 (SD = 0.63) to 2.88 (SD = 0.63).

Voluntary cough PEFR values of 3.41 L/s differentiate between “effective” and “ineffective” airway clearance for ≥ 80% of subglottic residue (aspirate material)
Improvements in peak expiratory airflow ($p < .001$) and airflow variability for PEFR and CEV ($p = .01$) were appreciated during smTAP.
What if I do not have access to all of that equipment....
Clinical Translation:
Voluntary Cough Skill Training

<table>
<thead>
<tr>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 hour</td>
<td>25 coughs</td>
<td>25 coughs</td>
<td>25 coughs</td>
<td>25 coughs</td>
</tr>
</tbody>
</table>

\[ \times 5 \text{ weeks} \]
Individuals with spinocerebellar ataxia can upregulate cough outcomes after one session of cough skill training.

Effects of Cough Training and Inspiratory Muscle Training on Cough Strength in Older Adults: A Randomized Controlled Trial
Hideo Kaneko1, Akari Suzuki1, Jun Horie2

Research Article
Respiratory–Swallow Coordination Training and Voluntary Cough Skill Training: A Single-Subject Treatment With Park
James A. Curtis, Avery

Research Article
Rehabilitation of Airway Protection in Individuals With Movement Disorders: A Telehealth Feasibility Study
Jordanna S. Sevitz,1 James C. Borders,2 Avery E. Dakin,3 Brianna R. Kiefer,4 Roy N. Alcalay,4 Sheng-Han Kuo,5 and Michelle S. Troche6,8

1Laboratory for the Study of Upper Airway Dysfunction, Department of Biobehavioral Sciences, Teachers College, Columbia University, New York, NY 2Department of Speech, Language, and Hearing Sciences, Purdue University, West Lafayette, IN 3Department of Neurology, Columbia University Irving Medical Center, New York, NY 4Department of Neurology, Tel Aviv Sourasky Medical Center, Israel
Cough Skill Training: A Step-by-Step Tutorial

**Gold Standard**
- Sensorimotor Training for Airway Protection (smTAP)
- Voluntary Cough Skill Training with Spirometry

**Clinical Implementation**
- Voluntary Cough Skill Training with Handheld Peak Flow Meters
Spirometry: Voluntary Cough Skill Training

Step-by-step guide

• Set target line 25% above maximum peak flow from voluntary cough testing
• Participant sits in front of computer screen
• Provide instructions with goal to exceed the target line
• Provide feedback based on performance
• Complete 25 repetitions (5 sets of 5 repetitions)

"Cough hard one time."
How can we translate this to clinical practice?

• Provide patient with handheld peak flow meter
• Set visual treatment target on the device
• Provide instructions
• Note the number and strength of their cough from handheld peak flow meter
• Provide feedback on performance

“Cough like something went down the wrong tube.”
Voluntary Cough Skill Training

Handheld Peak Flow Meter

Troubleshooting

• Lip seal
• Proper hand placement
• Reset dial before next trial
• Follow principles of motor learning related to feedback
• Avoid over-cueing
A Primer on Hypotussic Cough: Mechanisms and Assessment

Emilie R. Lowell¹ · James C. Borders¹ · Jordanna S. Sevitz¹ · Avery E. Dakin¹ · Danielle Brates² · Michelle S. Troche¹

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Thank you!