Management of Unilateral Vocal Fold Paralysis

Nelson Roy Ph.D., CCC-SLP
Marshall Smith M.D.

Department of Communication Disorders and Division of Otolaryngology- Head & Neck Surgery
Unilateral Vocal Fold Paralysis (UVFP) - Causes

- Malignant Disease (lung cancer, esophageal tumors, thyroid disease)
- Surgical Trauma (thyroid, lung resection, c. artery, ACDF)
- Idiopathic (Viral presumed, diagnosis of exclusion)
- Nonsurgical trauma (penetrating wounds, blunt trauma, chest wounds)
- Peripheral Neurologic Disease (toxins-lead, arsenic, Guillain-Barre)
- Miscellaneous (aortic arch aneurysm).
The Vagus (Cr. N. X)
Manifestations of UVFP

- Heterogeneous Group!!!!
- Voice and Non-voice related complaints…
  - Voice = Breathiness (aphonia), low volume, poor pitch control, high pitch (compensatory?), diplophonia, hoarseness, short phrase length (+/- MTD?).
  - Non-voice = increased effort & fatigue with speaking, weak-mushy cough, aspiration of liquids (dysphagia), +/-stridor (esp. exercise).
- Laryngeal Signs
Phonatory Effects of UVP

- Asymmetry of
  - position
  - stiffness
  - vocal fold vertical height
  - phase of mucosal wave
- Incomplete glottal closure
- Vocal process gap
- +/- Supraglottal hyperfunction
- Turbulent airflow
- Chaotic vibration
  - Subharmonics
  - Period doubling
Paralytic Position of the Vocal Folds

- Median
- Paramedian
- Intermediate
- Lateral
Left VFP

Maximum Abduction

Maximum Open Phase

Maximum Closed Phase
Left VFP

Maximum Abduction

Mediolateral Supraglottic Compression

Maximum Adduction
Left VFP

Maximum
Closed Phase

Maximum
Open Phase

Maximum
Abduction
Video Examples

- Unilateral paresis (partial RLN denervation) vs. paralysis (complete RLN denervation)
- 3 cases of UVFP - Note position and tension of paralyzed fold.
- +/- supraglottic compression
Laryngeal Features

Unilateral Vocal Fold Paralysis

Nelson Roy Ph.D.
The University of Utah
Clinical Assessment of UVFP

- Patient Self-Assessment
  - VHI, (V-RQOL)
- Perceptual Assessment (CAPE-V or other), ?hypernasality
- Laryngostroboscopic Assessment (glottal gap, mucosal wave, periodicity, phase asymmetry, vertical level of v.f. approx.)
- Voice Stimulability Testing (Essential).
- Physical Exam/Workup Etiology/LEMG?
  - Acoustic Assessment (a variety of measures, problems related to aperiodicity in UVFP)
  - Aerodynamic Assessment (glottal airflow, AC/DC ratio, Psub, laryngeal resistance, MPT)
Management Options for UVFP

1. Behavioral (Voice Therapy)-Voice Facilitation Techniques (Fade Cues… Increase complexity).
   - Manual Reposturing/Compression
   - Reduce maladaptive behaviors (elevated pitch, and excess extralaryngeal tension)
   - Alter Pitch-Loudness Characteristics, Glottal Fry
   - Head Turn
   - Pushing
   - Amplification

2. Surgery (no irreversible surgery ~ 6, 9, 12 mos. post onset)

3. Surgery plus Voice Therapy

4. Do Nothing (patient happy)… or… Wait and watch?
Surgical Options in UVFP

• Medialization/Augmentation
  – Injection Laryngoplasty

• Laryngeal Framework Surgery (Medialization)
  – Surgical implant
    • Goretекс, silastic, titanium, hydroxylapatite
  – Structural Repositioning
    • Arytenoid Adduction

• Reinnervation**
  – Ansa-RLN anastomosis

• Reinnervation plus Arytenoid Adduction
VF Augmentation/Injection
Laryngoplasty

- Bilateral vs. Unilateral?
- Location? (Most lateral to vocal ligament (in p.glottic space))
- How?…O.R. Procedure or Office…Peroral (Endoscopic-Guided), Transcutaneous (Endoscopic-Guided),
- What?….Injectables (Biocompatible?, durable?, viscoelastic properties?):
  - Gelfoam,
  - Autologous Fat,
  - Collagen…Zyderm, Zyplast (Bovine), Cymetra (cadaveric)
  - Radiance/Radiesse (Hydroxylapatite),
  - Hylaform (Hylan B Gel…Sweden), Restylane (Hyaluronic Acid)
  - Teflon (palliative patients).
Viscoelasticity

*Why is it important for vocal fold injectables?*
### TABLE II.
Dynamic Viscosity of Implantable Biomaterials and Human Vocal Fold Mucosal Tissues Measured at 10 Hz and Extrapolated to 100 Hz.

<table>
<thead>
<tr>
<th>Material Sample</th>
<th>Dynamic Viscosity (Pa-s)</th>
<th>Measured at 10 Hz</th>
<th>Extrapolated to 100 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polytetrafluoroethylene (Teflon)</td>
<td></td>
<td>116.144</td>
<td>10.186</td>
</tr>
<tr>
<td>Gelatin (Gelfoam)</td>
<td></td>
<td>21.297</td>
<td>2.335</td>
</tr>
<tr>
<td>GAX collagen (Phonagel or Zyplast)</td>
<td></td>
<td>12.844</td>
<td>1.480</td>
</tr>
<tr>
<td>Noncrosslinked collagen (Zyderm)</td>
<td></td>
<td>8.563</td>
<td>0.980</td>
</tr>
<tr>
<td>Human abdominal subcutaneous fat (70-year-old woman)</td>
<td></td>
<td>3.026</td>
<td>0.296</td>
</tr>
<tr>
<td>Vocal fold mucosa (72-year-old man)</td>
<td></td>
<td>2.702</td>
<td>0.281</td>
</tr>
<tr>
<td>Vocal fold mucosa (62-year-old man)</td>
<td></td>
<td>0.897</td>
<td>0.099</td>
</tr>
</tbody>
</table>

Extrapolation was based on simple linear least-squares regression (see Equation 3).

Chan RW, Titze IR, Laryngoscope 108:725-73, 1988
Viscoelastic Properties of Vocal Fold Injectables

Bohlin Rheometer

Vocal Fold micronized acellular dermal matrix (Cymetra®) Injection

• Lasts 2-12 months (longer than Gelfoam®)
• Office or OR procedure
• Can be repeated
• Favorable viscoelastic properties
Bioform “Radiesse FN”

Calcium hydroxylapatite microspheres
“FN” product: 25-45 microns in size

Localized radio-opaque implant
Is “biodegradable”
FDA Approved as a vocal fold implant
Video: In office injection

Injection
Laryngoplasty

Office Procedure:
- Peroral
- Transcutaneous
Autologous Fat Injection Site
Autologous Fat Injection
Fat Injection Video

Surgical Management of UVFP

Injection Laryngoplasty
Maximum Abduction

Atrophic Paralyzed Left Vocal Fold

Glottic Incompetence

Atrophic Left Fold

Maximum Adduction

PRE-VOCAL FOLD INJECTION
Surgical Options (cont’d)

Laryngeal Framework Surgery: Medialization-
Move affected vocal fold to midline
• Thyroplasty (Type I)- Goretex, silastic, others.
• Arytenoid Adduction
• Combination AA with Thyroplasty
Medialization Laryngoplasty
A Variety of Implants and Techniques

- Silastic
- Hydroxylapatite
- Titanium
- Goretex
Arytenoid Adduction

- Treatment of the posterior glottis
- Can do under general or local
- Can combine with reinnervation or thyroplasty
Framework Surgery: Type I Thyroplasty
Ansa Cervicalis Reinnervation

- Augmentation & Medialization (Thyroplasty) fail to re-establish tone in paralyzed fold!!!
- Option: ansa cervicalis (sternohyoid br.) RLN anastomosis
- NIH Clinical Trial (Medialization vs. Reinnervation)

Reinnervation vs. Medialization

Advantages and Disadvantages

- Reinnervation
  - Advantages
    - Reverse muscle atrophy
    - No foreign implant
    - Potential for ongoing improvement
    - No mucosal wave disruption
    - **More vocal flexibility**
  - Disadvantages
    - Slightly longer operating time
    - Waiting time for reinnervation (3-6 months)

- Medialization
  - Advantages
    - Immediate improvement
    - Adjust voice intraoperatively
  - Disadvantages
    - Potential for ongoing muscle atrophy
    - Foreign body implant
    - Static position, less flexibility
Reinnervation: Pre vs. Post
Unilateral Vocal Fold Paralysis Management

2005 – No consensus

- Medialization Laryngoplasty with
  - Silastic (Ford, Koufman, Mongtomery)
  - Goretx® (Hoffman, Zeitels)

- ML and Arytenoid Adduction (Hoffman, Woo, others, Abraham, Chester)

- Reinnervation (Crumley, Goding, Marionian, Paniello)

- Reinnervation + AA (Berke)

- Injection Laryngoplasty (fat, Cymetra®, Radiance®, Zyplast®)
Surgery vs. Voice Therapy

- Voice Therapy (Time Post-Onset?)
- Response to Stimulability Testing (\& Position of Paralyzed Fold)
- Motivation of Patient \& VHI
- Other
Voice Facilitating Techniques

- Head Turn
- Manual Reposturing/Compression
- Glottal Fry
- Pitch & Volume Adjustments
- Reduce maladaptive behaviors (elevated pitch, and excess tension)
- Pushing
- Amplification
Video Examples

- Stimulability Testing (manual reposturing + voice facilitating techniques)
- Voice Rx Effects (pre, intermediate, post-)
Voice Therapy - Video

Voice Stimulability Testing:
Case Illustrations
Vocal Fold Paralysis

*In the Future?*

4 x 4 Utah Electrode Array- Movement is possible!!
Utah Electrode Array implanted onto recurrent laryngeal nerve
Laryngeal Reanimation of the Paralyzed Vocal Fold – NIH R21, M. Smith PI

Electrode array in silastic cuff

Nerve histology of electrode pin
ESLN Paralysis
Phonatory & Laryngoscopic Features of External Superior Laryngeal Nerve (ESLN) Denervation: An In Vivo Model

Nelson Roy Ph.D.
Communication Sciences & Disorders

Marshall Smith M.D.
Otolaryngology-Head & Neck Surgery

Christopher Dromey Ph.D. & Ray M. Merrill Ph.D.
Brigham Young University

Cara Sauder M.A. & Kristine Tanner Ph.D.
The Voice Disorders Center

Skylee Neff B.S., Doug Grennan, B.S., Jonathan Redd B.S.
Communication Sciences & Disorders
Introduction

- The external branch of the superior laryngeal nerve (ESLN) innervates the cricothyroid (CT) muscle of the larynx, a vocal fold tensor “primarily” responsible for pitch elevation.
CT Muscle (2 bellies)

Elongation of the Vocal Fold with CT Contraction
Denervation= interrupted nerve supply (messages) to muscles

- Partial or Complete Denervation?
- Unilateral or Bilateral?
- 1 nerve or many?
- No electrical impulses from nerves = No muscle contraction= paralysis

If ESLN damaged on one side = unilateral CT paralysis
For over 100 years, a controversy has existed regarding the laryngeal and phonatory signs that should be considered pathognomonic of unilateral ESLN paralysis.

Myriad descriptions exist of the voice and laryngeal behaviors ostensibly associated with unilateral ESLN denervation.

To complicate matters, confusion surrounds whether voice and laryngeal manifestations reflect the pure effects of CT dysfunction, or alternatively, compensatory adjustments in response to prolonged denervation.

To date, no consensus exists regarding the clinical features of acute, unilateral ESLN denervation.
Purpose & Specific Aims

• To address this longstanding controversy, this exploratory investigation modeled “in vivo” acute, unilateral ESLN denervation by temporarily blocking the ESLN using lidocaine HCL, and verifying selective denervation using laryngeal electromyography (LEMG).

• By surveying a broad range of vocal tasks before and during the ESLN block, two specific aims were addressed:
  
  – (1) to describe the salient phonatory and laryngeal features associated with acute CT denervation.

  – (2) to identify a set of voice and laryngeal tasks that maximally provoke or expose ESLN dysfunction when present, thereby contributing to the development of improved clinical diagnostic protocols.
Methods

Participants
10 young, healthy adult males (non-singers), no history of past or present voice disorder
VRQOL = 99.8 (normal range = 90-100)
Mean Age = 25 yrs (SD 3.3; range 19-29)
Mean Lidocaine injected = 1.73 cc (SD .83 cc; range .5-3 cc)

<table>
<thead>
<tr>
<th>Subject #</th>
<th>Code</th>
<th>Age (yrs)</th>
<th>VRQOL Score</th>
<th>Lidocaine (cc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M01</td>
<td>28</td>
<td>100</td>
<td>2.8</td>
</tr>
<tr>
<td>2</td>
<td>M02</td>
<td>25</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>M03</td>
<td>25</td>
<td>100</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>M04</td>
<td>19</td>
<td>100</td>
<td>0.5</td>
</tr>
<tr>
<td>5</td>
<td>M05</td>
<td>25</td>
<td>100</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>M06</td>
<td>20</td>
<td>97.5</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>M09</td>
<td>27</td>
<td>100</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>M10</td>
<td>24</td>
<td>100</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>M11</td>
<td>28</td>
<td>100</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>M12</td>
<td>29</td>
<td>100</td>
<td>1</td>
</tr>
</tbody>
</table>
The CT is innervated by the ESLN, whereas the TA is innervated by the RLN. The TA muscle serves as a control to ensure selective ESLN block.
LIDOCAINE INJECTION SITE: above the inferior border of the thyroid cartilage where the nerve crosses the inferior cornu, and anterior to the posterior margin of the thyroid lamina.
Lidocaine Injection (Right ESLN) (<3 mls of 2% lidocaine with epinephrine)
LEMG Confirmation & Monitoring of Selective ESLN BLOCK

Pre-Block

During CT Block
Multiple Outcomes Measures: Acoustic, Auditory-Perceptual, Aerodynamic, Autoperceptive, and Endoscopic (FVLS)
Laryngeal Signs of Unilateral CT dysfunction: No Consensus

• Myriad descriptions exist of the laryngeal behaviors putatively associated with unilateral ESLN denervation including:
  – (2) decreased longitudinal tension and length of the ipsilateral vocal fold with glottic insufficiency secondary to mild bowing, (Ward, 1977; Dursun, Sataloff et al., 1996).
  – (3) sluggish ab- or adduction of the ipsilateral fold during repetitive phonatory tasks, (Heman-Ackah & Batory, 2003; Rubin et al., 2005).
  – (4) asymmetrical, irregular, or aperiodic vocal fold vibration, (Dursun et al., 1996; Mendelsohn et al., 2007)
  – (5) reduced vocal fold amplitude, and mucosal wave in some cases (Dursun, et al., 1996).
Flexible Videolaryngostroboscopy (FVLS)

- Surveyed a wide range of vocal tasks/maneuvers, combining various pitch and loudness conditions that would permit comprehensive assessment of laryngeal function using Flexible videolaryngostroboscopy (FVLS).

- Tasks were included that would evaluate all claims made in the literature regarding laryngeal features associated with ESLN paralysis.
Multiple Vocal Tasks (FVLS)

- Eleven blinded, expert judges, rated randomized pre- versus during block recordings of 10 vocal tasks using standardized FVLS rating protocols.
  - Laryngologists
    - Steven Bielamowicz M.D.
    - Mark Courey M.D.
    - Gaelyn Garrett M.D.
    - Albert Merati M.D.
    - Gregory Postma M.D.
    - James Thomas M.D.
  - Speech-Language Pathologists
    - Allison Behrman Ph.D.
    - Douglas Hicks Ph.D.
    - Bruce Poburka Ph.D.
    - Joseph Stemple Ph.D.
    - Ed Stone Ph.D.
- “Good” to “very good” intra- and inter-judge reliability or agreement depending upon the FVLS parameter assessed.
Specific Laryngeal Findings

Contrary to clinical reports...

- *no evidence of hypomobility/sluggishness* of the ipsilateral vocal fold, or a reliable pattern of axial rotation of the larynx during high pitch voice was observed.

- no evidence to support reduced vocal fold longitudinal tension/length, aryepiglottic fold length asymmetry, phase asymmetry, vocal fold plane differences, or glottic insufficiency, as diagnostic features of acute, unilateral CT dysfunction.
Dx Markers of ESLN Paralysis?

- The analysis revealed a pattern of:
  - (1) *deviation of the petiole of the epiglottis to the side of weakness (i.e., the right) in 60% of participants during a glissando up maneuver produced at normal volume,*
  - (2) *improved* glottic closure across high pitch voice tasks, and
  - (3) *axial rotation of the posterior commissure to the left and the anterior commissure to the right in 50% of participants during a maneuver which rapidly alternated between a maximum vocal fold abduction task (i.e., sniff) and a high-pitched “ee” production.*
Pre vs. During ESLN Block (M09)
Pre vs. During ESLN Block (M02)
Pre vs. During ESLN Block (M01)

Pre-

During Block
Pre vs. During ESLN Block (M04)
Pre vs. During ESLN Block (M05)

Pre-

During Block
Pre vs. During ESLN Block (M10)
M02 Pre vs. During ESLN Block

Pre-ESLN Block
M09 Pre vs. During ESLN Block

Pre-ESLN Block
M10 Pre vs. During ESLN Block

Pre-ESLN Block
ESLN Denervation Case?

53 y.o. part-time singer (bluegrass, rock, folk, blues)

No formal vocal training

6 month history of loss of pitch flexibility, and loss of uppermost part of singing pitch range following URI symptoms.

Mild speaking voice problems

Provisional Dx: R. ESLN paralysis

Refused LEMG
Clinical Case: R. ESLN denervation (Video example)
Conclusions: Acute ESLN Paralysis

- No evidence of vocal fold hypomobility, sluggishness, asymmetry during RPTs.
- No frank evidence of glottic insufficiency.
- Deviation of the petiole of the epiglottis to the side of weakness during GUNV may represent a valuable diagnostic marker of ESLN denervation.
- Additional clinical studies are needed to validate the model (acute vs. chronic denervation?).
Acknowledgements

• Grant from U of Utah CRR to the P.I. to support this research