The Aging Voice
From Clinical Symptoms to Biological Realities

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Voice: The Delicate Balance

Mild changes in each subsystem with age.

Changes can perturb the system & result in an altered voice signal.
Voice Changes with Aging

- Presbyphonia
- Prevalence
  - One of primary etiologies of voice concerns in the elderly (treatment-seeking population)
  - Prevalence in general population of aging adults unknown
  - Preliminary studies suggest prevalence may approach 30% of those over age 65 (Roy et al., 2007)
Presbyphonia

- Auditory Perceptual Changes
  - Altered Pitch - Gender Differences
  - Hoarseness
  - Breathiness
  - Strain
  - Slowed rate
Presbyphonia

- Visual Perceptual Changes
  - Bowing of vocal fold edge
  - Atrophy
  - Spindle-shaped gap
  - Prominence of vocal processes
  - Discoloration
  - Edema (female)
Presbyphonia

- **Acoustic Changes**
  - Increased Fo in males
  - Decreased Fo in females
  - Decreased SPL
  - Increased Noise to Harmonics Ratio
  - Inconclusive findings on changes in jitter and shimmer

- **Aerodynamic Changes**
  - Few studies
  - Suggest maintenance of mean airflow rate
  - Changes in LAR vary
  - May be gender differences
Impact

- Changes often of sufficient magnitude to be recognized by others
- Changes may negatively influence a listener’s perception of an aged speaker
- Impact on functional use of voice and ultimately quality of life
What Underlies Presbyphonia?

- Changes at multiple levels:
  - Subglottic Respiratory Tract
  - Supraglottal Vocal tract
  - Laryngeal / Glottal
What underlies presbyphonia?
Factors external to the larynx

Subglottic Respiratory Tract
- Calcif. of costal cartilages
- Respiratory muscles infiltrated by conn. tissue
- Decreased chest wall compliance & tissue recoil
- Decreased vital capacity
- Increased residual volume

Supraglottic Tract
- Endocranial space increases
- Tongue atrophies
- Muscles of the pharynx (vocal tract) weaken
- Larynx drops in the neck
What underlies presbyphonia?

Laryngeal Factors

- Changes at each major layer
  - Epithelium
  - Lamina Propria
  - Muscle
Epithelium

- Slight change in thickness
- Discoloration
  - Yellowish, Grayish
- Effect on phonation minimal
## Lamina Propria: Review

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superficial</td>
<td>Gelatinous; Layer of greatest mov’t in vibration</td>
</tr>
<tr>
<td></td>
<td>Primarily non-cellular</td>
</tr>
<tr>
<td></td>
<td>Extracellular Matrix (ECM)</td>
</tr>
<tr>
<td></td>
<td>Fibrous proteins (elastin, collagen, reticular)</td>
</tr>
<tr>
<td></td>
<td>Interstitial proteins (decorin, hyaluronic acid)</td>
</tr>
<tr>
<td>Intermediate</td>
<td>Less pliable than LPs</td>
</tr>
<tr>
<td></td>
<td>Primarily non-cellular</td>
</tr>
<tr>
<td></td>
<td>ECM</td>
</tr>
<tr>
<td></td>
<td>Fibrous proteins (elastin most abundant)</td>
</tr>
<tr>
<td></td>
<td>Interstitial proteins (hyaluronic acid, fibromodulin)</td>
</tr>
<tr>
<td>Deep</td>
<td>ECM</td>
</tr>
<tr>
<td></td>
<td>Fibrous proteins (collagen more abundant)</td>
</tr>
<tr>
<td></td>
<td>Interstitial proteins (fibromodulin)</td>
</tr>
</tbody>
</table>
Lamina Propria: Change with Age

- **LP<sub>S</sub>**
  - Change in layer thickness (increase/decrease)
  - Fibrous proteins more complex course; altered properties
  - Reduced elasticity

- **LP<sub>I</sub>**
  - Less thick (> prominent in males); Change in contour
  - Fibrous proteins (elastin) loose elasticity
  - Layer stiffens

- **LP<sub>D</sub>**
  - Fibrous proteins (collagen) more dense; multidirectional course
  - Layer becomes more fibrous
Lamina Propria: Mechanisms of Change

- Metabolic and enzymatic changes
  - Proteins destroyed at a slower rate; slower turnover
  - Older proteins with altered properties remain
- Fibroblast activity levels change
<table>
<thead>
<tr>
<th>Feature</th>
<th>TA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiber Types</td>
<td>I, IIA, IIX&lt;br&gt;Specialized isoforms in some animal models&lt;br&gt;Much co-expression&lt;br&gt;Differs across lat-med dimension</td>
</tr>
<tr>
<td>Arrangement</td>
<td>Mosaic pattern</td>
</tr>
<tr>
<td>Contractile Features</td>
<td>Rapid; speeds exceed limb SM&lt;br&gt;Fatigue-resistant</td>
</tr>
<tr>
<td>Motor Unit</td>
<td>Small motor units</td>
</tr>
<tr>
<td>Propriocep.</td>
<td>Spindle debated&lt;br&gt;Mucosal mechanoreceptors</td>
</tr>
</tbody>
</table>
Morphological Changes: TA

*Change in muscle cell leading to changes in overall muscle structure & function*

<table>
<thead>
<tr>
<th></th>
<th>TA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Muscle Fiber</strong></td>
<td>Reduced mass</td>
</tr>
<tr>
<td></td>
<td>? Pattern of fiber loss</td>
</tr>
<tr>
<td></td>
<td>Maintain type II (fast) fiber size</td>
</tr>
<tr>
<td><strong>Connective Tissue</strong></td>
<td>Connective tissue patterns not clearly defined</td>
</tr>
<tr>
<td><strong>Function</strong></td>
<td>Reduced speed</td>
</tr>
<tr>
<td></td>
<td>Reduced force</td>
</tr>
<tr>
<td></td>
<td>Reduced endurance</td>
</tr>
</tbody>
</table>
Mechanisms of Muscle Change

- Primary mechanisms of cellular change with age
  - Neurologic
  - Metabolic
  - Hormonal
  - Physical Activity
# Neurologic Mechanisms of Change

<table>
<thead>
<tr>
<th></th>
<th>TA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Motor</strong></td>
<td>□ No net loss of RLN fibers</td>
</tr>
<tr>
<td></td>
<td>□ Alterations in myelin sheath</td>
</tr>
<tr>
<td></td>
<td>□ Changes in NMJ (similar to denervation changes)</td>
</tr>
<tr>
<td><strong>Sensory</strong></td>
<td>□ Decreased # and size of SLN nerve fibers</td>
</tr>
<tr>
<td></td>
<td>□ Decreased density of sensory nerve endings</td>
</tr>
<tr>
<td></td>
<td>□ No info on proprioceptive change</td>
</tr>
</tbody>
</table>
# Metabolic Mechanisms of Change

<table>
<thead>
<tr>
<th></th>
<th>TA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mitochondria</strong></td>
<td>- Increased rate of mitochondrial mutation</td>
</tr>
<tr>
<td></td>
<td>- Abnormal accumulation of mitochondria</td>
</tr>
<tr>
<td></td>
<td>- May shift to &gt; glycolytic profile</td>
</tr>
<tr>
<td><strong>Vascular</strong></td>
<td>- Reduced blood flow</td>
</tr>
<tr>
<td></td>
<td>- Reduced capillary surface area</td>
</tr>
</tbody>
</table>
Hormonal Mechanisms of Change

May see shift in the anabolic-catabolic hormone balance in later life.

TA

- Decline in # of sex hormone receptors in larynx with age
- No studies examining shifts in hormone levels with morphological changes in TA
Muscle Change: Summary

- TA remodels with age
  - Muscle atrophy
  - Fiber loss
  - Increase in glycolytic metabolism
  - Increase in mitochondrial abnormalities

- In animal models, above changes alter the muscle’s contractile properties toward a slower, weaker, and less fatigue-resistant profile.
Muscle Change: Summary

- Likely due to changes in the peripheral nerve supply, decreased vascular support, systemic hormonal changes, and stochastic damage.
- Appropriateness of behavioral treatments for reversing the TA’s changes has not been documented.
Current Treatments

- **Surgical**
  - Vocal Fold Augmentation or Medialization
    - Belafsky et al. (2004)
    - Ford & Bless (1986)
    - Isshiki et al., (1996)
  - Effective in short-term. Long-term information limited.
Current Treatments

- **Behavioral**
  - Exercise shown to enhance muscle in limb skeletal muscle
    - Uncertain of effect on laryngeal muscle
  - **Proposed:**
    - Vocal Function Exercises
    - Laryngeal strengthening exercise
    - Studies showing treatment effectiveness with presbyphonia not available
Current Treatment: Summary

- Limited number of treatment options available
- Limited research supporting the use of current methods
- Area ripe for study as population ages
Future Directions in Treatment

- Molecular Biology / Tissue Engineering
  - Ongoing research into restoring lamina propria in cases of VF scar
    - Can similar approaches be applied to the aged VF?
  - Fibroblasts / Myoblasts
    - Can we stimulate fibroblasts to restore the LP?
    - Can we learn from limb muscle studies on myoblasts to facilitate muscle growth and counteract age-related atrophy?
Future Directions in Treatment

- Medical / Hormonal
  - Hormones known to influence muscle
    - Can we control the anabolic-catabolic forces medically to preserve VF muscle?
    - Risk vs Benefit?
Future Directions in Treatment

- Surgical
  - Demonstrate the long-term efficacy of current procedures (augmentation, medialization)
  - Consider application of new approaches, new injectables
Future Directions in Treatment

- Behavioral
  - Efficacy studies on application of behavioral approaches in elderly population
  - Determine mechanism by which exercise results in functional change.
  - Need objective means of measuring the effect of therapies on laryngeal biology
    - Muscle biopsy?
    - Myoblast / fibroblast activity
Future Directions

- Linking the basic and clinical sciences to enhance treatment options for the aging voice
- Dilemma of animal vs. human models of aging
- Realize that the future of voice care for the elderly (and other populations) may involve the SLP, ENT, and basic scientist
Selected References

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