Impact of congestive heart failure on voice and speech production: A pilot study

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**Motivation**

Noninvasive identification of volume overload is critical to maintaining stability of chronic heart failure (HF) patients. Current methods (e.g., weight monitoring) have limited reliability and only reflect changes that occur shortly before the onset of symptoms.

The goal of this study was to determine whether voice and speech changes in chronic HF patients hospitalized for acute decompensation during diuresis are correlated with measures of volume status such as weight, NT-proBNP, and symptoms.

**Hypotheses**

- Vocal fold edema lowers pitch and increases acoustic perturbation
- Volume overload increases the frequency of breaths during continuous speech

**Methods**

Ten HF patients with acute decompensation were studied. The following voice and cardiac-related assessments were performed:

**Daily**
- Physical exam
- Sustained vowels
- Standard reading passage (Rainbow Passage)

**Admission and discharge**
- Plasma NT-proBNP
- Dyspnea visual analog scale (DVAS)
- Global symptoms visual analog scale (GVAS)

**Voice and speech measures** computed from a vowel’s most stable 1-second segment:
- (A) waveform (jitter)
- (B) spectrum (energy ratio)
- (C) cepstrum (CPP)

**Respiratory**
- ΔWeight (kg)
- ΔNT-proBNP (pg/ml)
- ΔDVAS

**Cardiac**
- ΔBaseline BNP (pg/ml)
- ΔBaseline weight (kg)

**Acoustic**
- ΔPitch stdev (Hz)
- ΔJitter (pts)
- ΔCPP (dB)

**Time Course of Changes in Physiologic Markers of Heart Failure Decompensation**

**Results**

**Patient number**

<table>
<thead>
<tr>
<th>Patient number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)/Sex</td>
<td>62/F; 76/M</td>
<td>65/M; 68/M</td>
<td>68/M</td>
<td>70/M</td>
<td>76/M</td>
<td>84/M</td>
<td>69.5 ± 12.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline BNP (pg/ml)</td>
<td>3712</td>
<td>2201</td>
<td>3766</td>
<td>1919</td>
<td>2900</td>
<td>11521</td>
<td>6866</td>
<td>31601</td>
<td>7204 ± 9040</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline weight (kg)</td>
<td>88.0</td>
<td>79.0</td>
<td>116.6</td>
<td>61.4</td>
<td>122.5</td>
<td>104.9</td>
<td>119.7</td>
<td>127.7</td>
<td>78.5</td>
<td>90.6</td>
<td>98.8 ± 22.5</td>
</tr>
</tbody>
</table>

**Δ Measure**

<table>
<thead>
<tr>
<th>Measure</th>
<th>ΔPitch stdev (Hz)</th>
<th>ΔJitter (pts)</th>
<th>ΔCPP (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean ± SD</td>
<td>0.73 ± 0.20</td>
<td>-0.12 ± 0.06</td>
<td>-1.05 ± 5.46</td>
</tr>
<tr>
<td># improved</td>
<td>8 of 10</td>
<td>8 of 10</td>
<td>6 of 10</td>
</tr>
</tbody>
</table>

**Total changes in selected measures from admission to discharge**

<table>
<thead>
<tr>
<th>Measure</th>
<th>ΔMeasure</th>
<th># improved</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔPitch</td>
<td>1.50</td>
<td>7 of 10</td>
</tr>
<tr>
<td>ΔPhonemes per phrase (maximum)</td>
<td>4</td>
<td>7 of 10</td>
</tr>
</tbody>
</table>

**Discussion**

Measures of voice stability and respiratory capacity correlate with improvements in HF patients after diuresis:

- Overall acoustic irregularity (CPP)
- Pitch instability (pitch standard deviation, jitter)
- Respiratory stress (phonemes per phrase)

**Future work**

**Current data analysis:**
- Analyze measures from neck-surface accelerometer
- During-stay changes in weight vs. voice measures
- Computation of additional voice and speech measures

**Future data collection:**
- Laryngeal endoscopy to image HF impact on vocal fold tissue
- Enroll healthy controls matched for age and comorbidities
- Additional speech and respiratory assessment tasks

**Future Work**

**Acknowledgments**

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**References**

