Characterization of Loading Environment on Human Ribs during Respiration

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INTRODUCTION

- Respiration is a combination of air flowing in and out of lungs during inhalation and exhalation, resulting from a change in the pressure differential. Breathing is aided by the muscles of respiration and subsequent movement of the ribs, which change the volume of the thoracic cavity. Movement of the thoracic skeleton results in differential strain on ribs, potentially causing microfractures. Microfractures can weaken the structural integrity of the rib, increasing its susceptibility to fail.

- The rib cage is composed of 12 ribs per side; 7 true ribs articulating directly with sternum, 3 false ribs attached via costal cartilage, and 2 floating ribs (Figure 1). Each rib has a cutaneous and pleural cortex, and the length can be divided into 3 sections: Posterior = 30% of curve length (CvLe), Lateral = 60% of CvLe, Anterior = 90% of CvLe (Figure 2).

- No investigations have been conducted to determine normal strains experienced by the ribs during respiration. The pleural side of rib could experience a different strain mode than the cutaneous side, and different locations along the rib length could experience differences in strain magnitudes.

- The objective of this study is to compare strain values between bilateral rib pairs during respiration, quantify variations in strain mode between the posterior, lateral, and anterior aspects of the rib, and note differences in strain magnitudes between the posterior, lateral, and anterior aspects of the rib.

METHODS

- Study Sample (n=1)
  - Post Mortem Human Subject
    - Male, 75 years old
    - 68 inches, 183 pounds; BMI = 28
    - Lumbar abMD T-score = 1.9
    - No history of invasive thoracic surgery

METHODS CONTINUED

TEST MATRIX

<table>
<thead>
<tr>
<th>Test #</th>
<th>Breath Pattern</th>
<th>Instrumentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-4</td>
<td>Normal (x3), Deep (x3), Normal (x3)</td>
<td>Chestband &amp; Cutaneous Strain Gauges</td>
</tr>
<tr>
<td>5-8</td>
<td>Normal (x3), Deep (x3), Normal (x3)</td>
<td>Cutaneous Strain Gauges only</td>
</tr>
<tr>
<td>9-12</td>
<td>Normal (x3), Deep (x3), Normal (x3)</td>
<td>Cutaneous &amp; Pleural Strain Gauges</td>
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</tbody>
</table>

Instrumentation

- Chestband placed on the axillary region of the sternum (Figure 3).
- During Phase II the strain gauge placement consists of strain gauges on the manubrium and body of the sternum, as well as 3 strain gauges on the cutaneous side of the ribs at the 30%, 60%, and 90% of the rib positions (Figure 4).
- During Phase III an additional 3 strain gauges will be placed on the pleural side of the rib at the corresponding 30%, 60%, and 90% positions.

Figure 2. Labeled Rib

Figure 3. Volunteer with Chestband

Figure 4. Anterior view (left) and posterior view (right) of rib cage

EXPECTED RESULTS

- Phase II will be verified by matching chestband data with Phase I results. The preliminary results from the cutaneous strain gauges will show variations in strain in the ribs. It is expected that the bilateral pairs of ribs will experience higher strain on the right side of the thorax than the left due to the size difference in the lungs.

- Phase III will be verified by cutaneous strain gauge data matching strain gauge data from Phase II. After analyzing the pleural strain gauge data in combination with the cutaneous strain gauge data, it is expected that the ribs will experience a straightening effect during respiration producing compression on the cutaneous cortex and tension on the pleural cortex. Additionally, the greatest strain is anticipated to be on the sternal side of the rib and will decrease along its length towards the vertebral side due to the expected motion of rib bending during inhalation.

CONCLUSIONS

- This study is necessary to create a baseline for ribs strain in a regular loading environment. The next steps would be to conduct the cutaneous and pleural strain tests, then analyze the resulting data to determine variations in strain. Use of these data could significantly improve biodeformal modeling efforts.

- Identifying the normal range of strain modes and magnitudes that the ribs are adapted to can lead to increased understanding of rib behavior during abnormal loading scenarios.

REFERENCES CITED

ACKNOWLEDGMENTS

CONTACT INFORMATION:

Cagle, B. 2013. Investigation of respiratory induced strain variation in the chest using strain gauges. Master's thesis. Northeastern University, Boston, MA.