Quantifying Peripheral and Central Lung Response to Bronchodilator in Asthma with Hyperpolarised 3-Helium MRI

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Introduction

- Hyperpolarised 3He MRI is sensitive to regional ventilation changes in response to bronchodilator in asthmatics [1]
- Lung ventilation can be quantified as the percentage of the total lung volume ventilated (Vv%) [2]
- The understanding of small airway involvement in asthma is currently limited [3]

Aim: To quantify lung ventilation response to bronchodilator in patients with asthma on a global and regional basis

Methods

- 34 moderate-severe uncontrolled asthmatics (GINA 2-5)
- MRI
  - 1.5T MRI system (GE HDx, USA). 3He vest coil (Clinical MR Solutions, USA)
  - MRI protocol as outlined in Figure 1 before and after use of a short-term bronchodilator:
    - Breath-hold 1, FRC + 1L, air, baseline
      - High resolution proton images (14s duration, spatial resolution: 1.5 x 2 x 10mm, full lung coverage)
    - Breath-hold 2, FRC + 350ml hyperpolarised 3He + 650 ml N2, baseline
      - 3He ventilation images (9s duration, spatial resolution: 3 x 3 x 10mm, full lung coverage)
      - Low resolution proton images during the same breath-hold [4] (5s duration, 3 x 6 x 10mm, full lung coverage)
    - Breath-holds 3 and 4, scans were repeats of breath-holds 1 and 2 respectively 20 minutes post-bronchodilator

Analysis

- Segmentation and registration was carried out in Slicer 3D [5]
- Ventilated volume (Vv) was segmented from the 3He images by applying a signal intensity threshold [2] and manually excluding large airways (figure 2 (a, b))
- Lung volume (LV)
  - The high resolution proton scan was registered to the low resolution (same-breathhold as 3He) proton scan
  - Lung volume was segmented using a seed region growing algorithm (figure 2(c))
  - Lung volume was divided into core and peel regions in MATLAB (Mathworks, Natick) (figure 2(d))
    - Peel represented the peripheral 1/3rd of the lungs, containing mainly small airways
    - Core represented the central 2/3rd of the lungs, containing the conducting airways
- Percentage ventilated volume (Vv%) was calculated: Vv% = Vv/LV, globally and for core and peel regions

Results

Table 1: relationships between mean regional Vv% values at baseline and post-bronchodilator

<table>
<thead>
<tr>
<th>Time-point</th>
<th>Region</th>
<th>Vv (%)</th>
<th>relationship</th>
<th>Time-point</th>
<th>Region</th>
<th>Vv (%)</th>
<th>p-value</th>
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</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>Core</td>
<td>92.5</td>
<td>&gt;</td>
<td>Baseline</td>
<td>Peel</td>
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<tr>
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<td>94.6</td>
<td>&gt;</td>
<td>Post-bronchodilator</td>
<td>Peel</td>
<td>84.4</td>
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<tr>
<td>Baseline</td>
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<td>92.5</td>
<td>&lt;</td>
<td>Baseline</td>
<td>Core</td>
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<tr>
<td>Baseline</td>
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<td>Post-bronchodilator</td>
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</tbody>
</table>

Conclusion

- Core and peel regional analysis of hyperpolarised 3He MRI provides a technique for evaluation of small airways disease
- Regional Vv% measurements suggested a bias towards small airway involvement in both asthma pathology and in response to short acting bronchodilator treatment in a cohort of 34 patients with moderate to severe asthma.