Assessment of Bone Marrow Oxygenation Based on T2* and T2 Changes Following Oxygen Inhalation

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Introduction

MR relaxometry (T1, T2) techniques have been shown to be useful in osteoporosis studies (1). Patients with osteoporosis have prolonged marrow T2* due to reduced magnetic field inhomogeneities in less dense trabecular bone (2). Accumulation of fatty marrow in osteoporotic bone is believed to increase the marrow T2 of subjects with reduced bone mineral density (BMD) (2,3). Deoxyhemoglobin is paramagnetic and breathing carbogen or pure oxygen lowers deoxyhemoglobin concentration and increases both T2* and T2 of water in blood and in the tissue surrounding blood vessels (4,5). Our aim in this study was to verify whether oxygen inhalation has a measurable effect on bone marrow T2* and T2 relaxation times.

Material and Methods

Seven healthy volunteers (4 males and 3 females; mean age 35 years) were examined in the supine position on a 3.0T scanner (Achieva, Philips Healthcare, Best, The Netherlands) using a standard spine coil. Air or 100% oxygen was delivered via a tight-seal full-face mask (Mirage NV, ResMed, Sydney, Australia) at a rate of 15 L/minute. A 10 mm thick axial image was acquired from each vertebral body L3, L4 and L5 for relaxation measurements before (T2* air and T2 air) and after 5 minutes of oxygen inhalation (T2* oxygen and T2 oxygen). A multi-echo fast field echo sequence (TR/TE/δTE 93/1.9/1.5 ms; 12 echoes; in-plane pixel size 1.5×1.2 mm) was used to measure T2*.

Results

Twenty-one pairs of T2* and T2 values before and after breathing oxygen were obtained from the 3 vertebral bodies of all 7 subjects. Table below summarizes the results after breathing air and pure oxygen for 5 minutes. On average, T2* increased by 11.7% compared to 7.9% for T2. Pair t-test showed that there were significant differences in T2* (p = 0.002) and T2 (p < 0.0001) values when breathing air or oxygen.

<table>
<thead>
<tr>
<th></th>
<th>T2* air</th>
<th>T2* oxygen</th>
<th>T2 air</th>
<th>T2 oxygen</th>
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<tbody>
<tr>
<td>Range (ms)</td>
<td>1.15 – 3.07</td>
<td>1.21 – 3.79</td>
<td>28.63 – 52.15</td>
<td>30.10 – 55.11</td>
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<tr>
<td>Mean ± SD (ms)</td>
<td>1.80 ± 0.58</td>
<td>2.01 ± 0.76</td>
<td>39.52 ± 6.26</td>
<td>42.66 ± 6.83</td>
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Conclusion

T2* changes after breathing carbogen or oxygen have been used to study tumor vascular architecture (4). Our results were the first to report that similar effects can be observed in the human bone marrow. Oxygen-rich blood transported into the marrow cavity reduced the amount of deoxyhemoglobin in the marrow vasculature and surrounding tissues thereby prolonging marrow T2* and T2. Apart from susceptibility differences at the marrow-bone boundaries influencing T2* decay, iron-rich red bone marrow might also play a role. T2* change (11.7%) was higher than T2 change (7.9%) after oxygen inhalation probably due to higher oxygen demand (and blood supply) in the red marrow compared to fatty marrow. Further studies involving subjects with different BMD are necessary to confirm our initial results.

References