Whole-Brain Functional and Diffusion Tensor MRI in Human Participants with Metallic Orthodontic Braces

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Introduction
MRI acquired using echo-planar-imaging (EPI) sequences are very sensitive to susceptibility artifacts in the presence of metallic objects, which presents a significant barrier for performing functional MRI (fMRI) and diffusion-tensor imaging (DTI) in patients with metallic orthodontic materials and other head implants.

Purpose: To evaluate the ability to reduce susceptibility artifacts in healthy human subjects wearing metallic orthodontic braces for two alternative approaches: T2-prepared (T2prep) fMRI,2,5 and diffusion-prepared DTI with 3D fast-gradient-echo readout.4

Method

Figure 1. Pulse sequence diagrams of (A) 3D T2prep BOLD fMRI, (B) conventional 2D multi-slice GRE EPI BOLD fMRI, (C) 3D diffusion-prepared DTI, and (D) conventional 2D multi-slice SE-EPI DTI. One entire image volume was acquired in a single repetition time (TR) period in all sequences to avoid the well-known phase errors in multi-shot approaches.

Six healthy participants (40±6yo, 3 females) were scanned at a 3T MRI scanner. Removable dental braces with bonding trays were used so that MRI images can be acquired with and without braces in the same participants. T2prep-fMRI and diffusion-prepared DTI (Figure 1) were performed in healthy human subjects. Results were evaluated in regions with strong EPI dropout regions for fMRI and the interior from-occipital fasciculus (FOF) for DTI, and minimal motor cortex for fMRI, and the posterior limit of internal capsule (PLIC) for DTI susceptibility artifacts. Signal-to-noise ratios (SNR), contrast-to-noise-ratio (CNR) for fMRI, apparent-diffusion-coefficient (ADC) and fractional-anisotropy (FA) for DTI, and degree of distortion (quantified with the Jaccard index (JI) that measures the similarity of geometric shapes) were compared in regions with strong or minimal susceptibility effects between the current standard EPI sequences and the proposed alternatives using paired t-test.

Results: fMRI

Table 1. Group-averaged quantitative results from all subjects for the comparison of GRE EPI BOLD fMRI with T2prep BOLD fMRI. p values within the range of 0.05 are highlighted with the corresponding t-scores from the GLM analysis with identical statistical threshold. The range of the t-scores is indicated by the scale bar.

<table>
<thead>
<tr>
<th>With braces</th>
<th>Dropout region</th>
<th>EPI</th>
<th>T2prep</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor cortex</td>
<td></td>
<td>37.8 ± 2.38</td>
<td>37.0 ± 2.45</td>
<td>0.06</td>
</tr>
<tr>
<td>Without braces</td>
<td></td>
<td>41.6 ± 5.92</td>
<td>44.4 ± 2.23</td>
<td>0.10</td>
</tr>
</tbody>
</table>

Table 2. Group-averaged quantitative results from all subjects (n=6) for the comparison of SE-EPI and diffusion-prepared DTI approaches. In the IFOF close to the braces, SNR was significantly diminished in SE-EPI, whereas diffusion-prepared DTI showed greater SNR and ADC and FA. SNR, ADC (10°/mm²) and FA of the internal capsule (PLIC) are highlighted with the corresponding t-scores from the GLM analysis with identical statistical threshold. The range of the t-scores is indicated by the scale bar.

<table>
<thead>
<tr>
<th>With braces</th>
<th>Dropout region</th>
<th>SE-EPI</th>
<th>Diffusion-prepared DTI</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fronto-occipital fasciculus</td>
<td></td>
<td>3.77 ± 0.70</td>
<td>5.73 ± 1.09</td>
<td>0.03*</td>
</tr>
<tr>
<td>Inferior fronto-occipital fasciculus</td>
<td></td>
<td>6.97 ± 1.29</td>
<td>6.18 ± 0.48</td>
<td>0.27</td>
</tr>
</tbody>
</table>

Table 2 summarizes the group-averaged quantitative results from all subjects from the ROI analysis (ROIs delineated in Figure 3). ADC, FA and SNR values were all comparable between diffusion-prepared and SE-EPI in the PLIC, a structure minimally affected by the susceptibility artifacts. In the IFOF, which is close to the dental braces, SNR was significantly diminished in SE-EPI, leading to erroneous ADC and FA values, whereas diffusion-prepared DTI showed greater SNR and resultant lower Jaccard index (JI) in each slice, P<.001, and the degree of distortion varied with the location of the slice.

Conclusion
T2prep-fMRI and diffusion-prepared-DTI can acquire functional and diffusion MRI, respectively, in healthy human subjects wearing metallic dental braces with less susceptibility artifacts and geometric distortion than conventional EPI images. These two sequences are expected to provide an alternative approach in studies suffering from large susceptibility artifacts, for instance in the presence of metallic implants in the brain, or for adolescents wearing braces.

References


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