Whole brain BOLD functional MRI in the presence of metallic orthodontic braces

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PURPOSE: Typical EPI based BOLD fMRI sequences are known to be sensitive to susceptibility effects caused by metal implants in the head, rendering large dropout and distortion in the presence of metallic objects. For instance, dental braces contain various metallic materials, which can cause large artifacts that extend into the brain in EPI BOLD images. This impedes the application of fMRI and is particularly a problem for fMRI studies involving teenage participants. According to the American Association of Orthodontics, 80% of the teenagers in the US and 33% of the world's population have orthodontic treatments at some point in their lives, and the number of adults seeking orthodontic treatment has been increasing steadily in the past 30 years (www.aaoinfo.org). Various methods have been developed to improve the image quality for near metal imaging (1). However, scan times required for whole brain acquisition in these methods are much longer than typical temporal resolution for fMRI. The recently developed T2prep BOLD fMRI method (2) uses a readout similar to MPRAGE, which is much less sensitive to susceptibility effects due to its short TE (<2ms) and high bandwidth. In this study, we evaluate the gradient echo (GRE) EPI BOLD and T2prep BOLD approaches for whole brain resting state fMRI in the presence of metallic orthodontic braces at 3T.

Fig. 2 Representative images from one subject wearing metal dental braces.

METHODS: *Dental braces*: A pair of bonding trays (Fig. 1) were used for our experiments, which can be easily mounted on and removed from the subject's teeth. Stainless steel brackets were bonded to trays made of hard plastic. A Beta-Titanium archwire was seated and secured in the bracket slots. *Experiments* were performed on a 3T Philips scanner. A 32-channel phased-array head coil (Nova) was used for RF reception and a body-coil quadrature coil for transmit. Four 10-min resting state fMRI scans were performed in each session with the combination of with/without braces, and GRE EPI/T2prep BOLD. Common parameters for all fMRI scans: 48 slices, voxel=2.5mm isotropic, TR=3s. GRE EPI: TE=30ms, FA=75º, SENSE=2, fat suppression. T2prep BOLD: TE=70ms, FA=21º, SENSE=2x2(APxFH), centric phase encoding. Higher-order shimming was applied in EPI scans. Anatomical images were acquired using MPRAGE. *Data analysis* was carried out with SPM8 and Matlab6. Preprocessing included realignment, slice time correction, co-registration, segmentation, normalization; nuisance removal (CompCor), regression of global mean and motion parameters; spatially smoothing (5mm FWHM kernel) and temporal filtering (0.01-0.1Hz). Temporal SNR (tSNR) was calculated as the signal divided by standard deviation along the time course. The dropout region in GRE EPI images due to the presence of metal braces was manually delineated. Note that the dropout area from the original GRE EPI images *without* braces was excluded from that region. *Seed-based analysis* was carried out using the brace dropout region as a seed, and whole brain connectivity maps were calculated.

Fig. 1 Dental brace bonding tray.

RESULTS: Fig. 2 shows images from scans with the metal braces. While no visible artifact in the brain can be observed on the anatomical (MPRAGE) images, large signal voids in frontal and temporal regions are seen on the EPI BOLD fMRI images. Similar to MPRAGE images, no visible artifacts can be observed on T2prep BOLD fMRI images in the entire brain. Fig. 3 shows the histograms of the image intensities in the EPI dropout region and whole brain in each methods. The image intensities in the EPI dropout region were close to zero in EPI images, while in T2prep BOLD images, the distribution of image intensities closely resembled that in the whole brain, indicating preserved sensitivity. The tSNR in the dropout region (15±11) was much lower than other grey matter (GM) areas (55±27) in the brain in EPI BOLD scans, whereas it was comparable between dropout (38±7) and other GM regions (48±23) in T2prep BOLD scans. Without braces, the whole brain connectivity map (Fig. 4) to the EPI dropout region (frontal) in the conventional GRE BOLD scans showed significant connectivity in several temporal and occipital areas, consistent with existing functional connectivity literature. On the other hand, with braces, the dropout region in GRE EPI scans showed correlations mostly to itself and some voxels outside the brain. In T2prep BOLD scans, the whole brain connectivity maps with and without braces did not show substantial difference (images not shown).

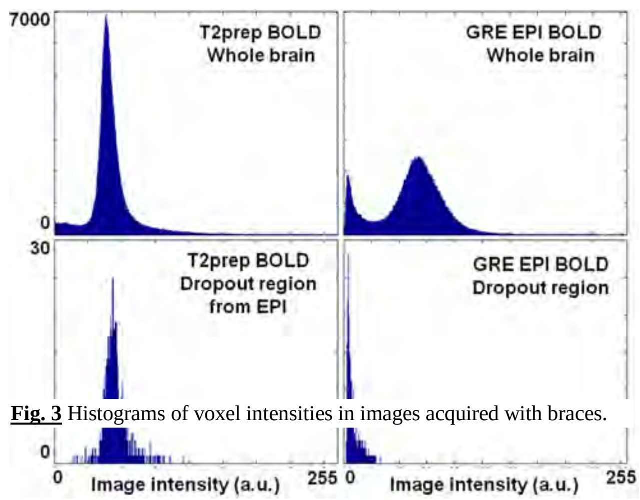
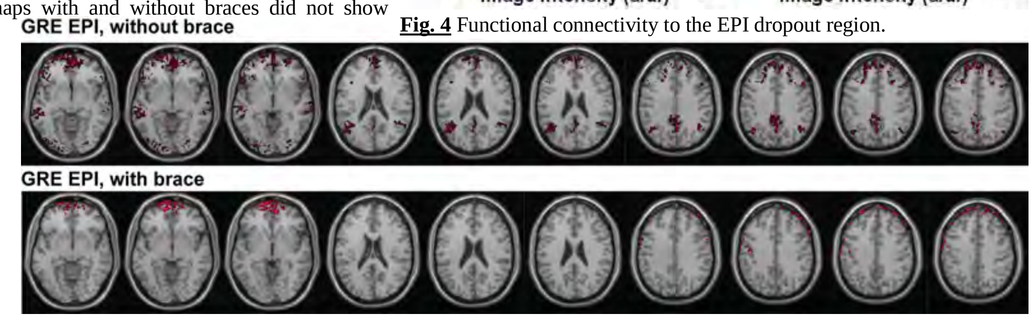


Fig. 3 Histograms of voxel intensities in images acquired with braces.

Fig. 4 Functional connectivity to the EPI dropout region.



DISCUSSION: Although the tSNR in the EPI dropout region with braces was still slightly positive (mainly because physiological noise is dominant in fMRI data), the BOLD sensitivity in this region may be substantially compromised due the susceptibility gradients caused by the metallic braces (3). This is evident in the whole brain connectivity maps to the dropout region. Alternatively, spin echo (SE) EPI BOLD fMRI should alleviate the dropout problem. However, its spatial resolution and coverage, as well as TR are limited largely by its power deposition, primarily from the large number of refocusing RF pulses in the readout. Under the FDA SAR limit, we were not able to run a SE EPI scan with the same geometry and TR as the GRE EPI and T2prep BOLD scans in this study.

CONCLUSION: We demonstrated the feasibility of performing dropout free whole brain BOLD fMRI in the presence of metallic braces using T2prep BOLD fMRI.

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Reference: (1)Koch, MRM 2011;65:71. (2)Hua, MRM 2014; (3)Deichmann, Neuroimage 2003;19:430.