Towards Dynamic Shimming for fMRI

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Introduction The imaging magnetic field in the human inferior portion of the frontal lobe (IFL) is seriously distorted. The shims of conventional clinical scanners are not able to correct the field to a satisfactory level. To compensate the shimming deficiency, there is increasing interest [1-3] in local shimming in which the shimming fields have a smaller scale of spatial variation, comparable to the target region. Previously, we have shown [4,5] that local shimming for IFL can be achieved by using the fields generated by current carrying coils held in the subject's mouth. It is found [5] that the improved field homogeneity can recover signal loss and enhance the sensitivity in time-series analysis in functional MRI (fMRI), thus increasing the extent of neuronal activity detected by fMRI. It is also noted [5] that the distance between the IFL and the location that the shim coil is held is about twice larger than the maximum diameter of a coil that can be comfortably held in the mouth, so the field generated by the oral shim coil of simple geometry is relatively uniform in comparison with the complex, small-scale structured field distortion in the IFL. Nevertheless, it is possible to obtain better results by dividing the ROI into smaller regions and shim and acquire each region's image separately. In this work, we discuss this problem and develop a solution of dynamical shimming.

Methods The details of the localized shimming are given in Ref. [5]. In short, a set of circular coils are held in the subject's mouth; then, in turn, each coil is given a test current and a magnetic field (B_0) map is obtained to determine the field it generates. A background B_0 map without any current is also acquired. The scanner operator prescribes a region of interest (ROI) and the pixels in the ROI are used to compute the shim currents through a linear least-square fitting to zero the background B_0 map. Thus the shimming field is optimized for the ROI of the operator's choice. To assess the effectiveness of applying the divided-ROI scheme for local shimming, a volume in the IFL which involved three slices was prescribed. Separate experiments were carried out with shim currents optimized for the whole ROI (volume shimming) and for each partial ROI in the three slices (slice shimming). The experiment was carried out at 1.5 T. A spiral pulse sequence [6] was used for fast data acquisition. The B_0 maps were acquired at T_E = 6 ms.

Results and Discussion The results are collected in Figure 1. The boxes in Fig. 1b indicate the ROI. The slice shimming (Fig. 1d) improves the images over the volume-shimmed ones (Fig. 1c) subtly for T_E = 6 ms. However, long T_E is preferred in fMRI for ideal BOLD contrast; and at T_E = 40 ms, slice shimming (Fig. 1f) improves over volume shimming (Fig. 1e) considerably. The improvement (Fig. 1g) includes an overall signal intensity increase and signal recovery at the boundaries. The present results suggest that one can take advantage of the better shimming results by smaller ROIs and vary the ROI location dynamically according to the slice selection during a multi-slice MRI scan. This will be very useful in fMRI, in which the data are usually acquired slice-wise. Implementing dynamic shimming with conventional linear shims has been successful in the past [7,8]. Such a dynamic shimming for local shimming is under development by the authors.

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References [1] JL Wilson *et al.*, Magn Reson Med **48**, 906 (2002); Neuroimage **19**, 1802 (2003). [2] V Roopchansingh *et al.*, In: Proc 12th ISMRM, 1650 (2004). [3] EC Wong and Y Mazaheri, In: Proc 12th ISMRM, 520 (2004). [4] J-J Hsu and GH Glover, In: Proc 11th ISMRM, 734 (2003); In: Proc 12th ISMRM, 994 (2004). [5] J-J Hsu and GH Glover, Magn Reson Med (in press). [6] GH Glover and S Lai, Magn Reson Med **39**, 361 (1998). [7] AM Blamir *et al.*, Magn Reson Med **36**, 159 (1996). [8] G Morrell and D Spielman, Magn Reson Med **38**, 477 (1997).

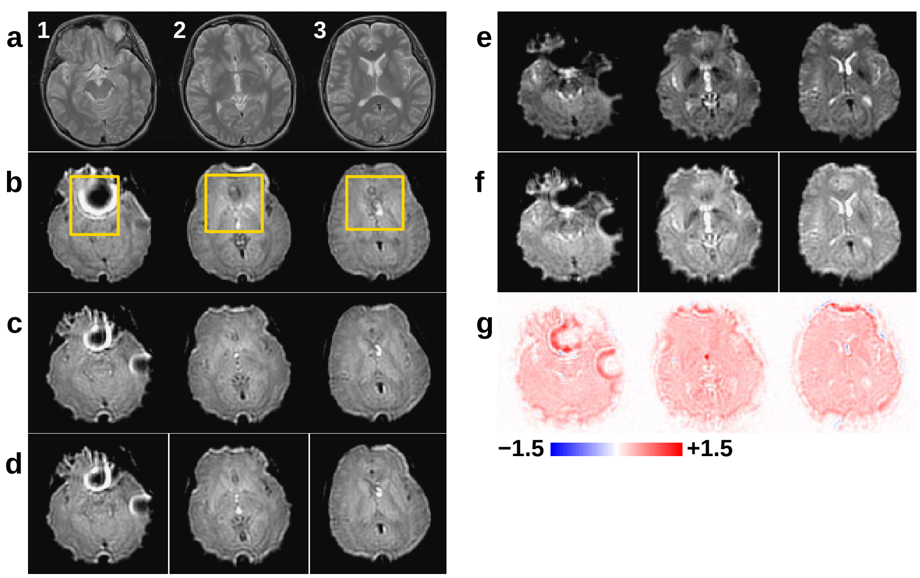

Figure 1 Images of IFL of a healthy volunteer. (**a**) Anatomic images by fast-spin-echo scan. (**b**)-(**d**) Spiral-scan images taken at T_E = 6 ms: (**b**) without local shimming, (**c**) with volume local shimming, (**d**) with slice local shimming. (**e**)-(**f**) Spiral-scan images taken at T_E = 40 ms: (**e**) with volume local shimming, (**f**) with slice local shimming. (**g**) Difference between (**f**) and (**e**); the color scale represents the ratio of the difference to the average pixel intensity of (**e**). (**d**) and (**f**) are collections of slices from scans in which the shim currents were optimized solely for the partial ROI of the selected slice. For all images, the slice thickness was 5 mm and the gap between slices was 5 mm.