T2-Prepared BOLD fMRI

Vincent DENOLIN¹, Thierry METENS²

¹Université Libre de Bruxelles, Systemes Logiques & Numeriques, Brussels, Belgium; ²Université Libre de Bruxelles, Hopital Erasme, MR Unit, Brussels, Belgium;

Introduction
T2*-weighted sequences are by far the most widely used in fMRI because of their superior sensitivity as compared to spin-echo sequences (1). However T2-weighting remains an interesting alternative since it better selects the response from small veins (2), which are thought to be closer to the actual site of activation. Here we present a new technique combining the advantages of both T2- and T2*-weighting, by means of a T2-preparation phase (3) and various gradient-echo-planar (GE-EPI) acquisitions. This offers an elegant way of tuning the degree of spin- and gradient-echo-like behavior of the fMRI sequence.

Methods
The T2 preparation phase consisted of three RF pulses, 90°/180°/-90°, the interval between the center of consecutive pulses being 25 ms. The T2-weighting produced is similar to that obtained with a spin echo sequence with TE=50ms. A spectral fat suppression (SPIR) was added immediately afterwards. Following these prepulses, which were common to all acquisitions, three different T2*-weighted segmented EPI sequences were initiated : a 2D multi-slice transient-field-echo-planar (TFE-EPI), a 3D TFE-EPI and a 3D fast-field-echo-planar (FFE-EPI), all with a 38ms echo time and a 20° flip angle. These sequences were implemented on a 1.5T clinical system (Philips Gyroscan Intera). The acquisition matrix was 64*39 (42 for 3D FFE-EPI), with a field-of-view 230*184. The slice thickness was 3.5mm with no gap. A shimming procedure was applied previously to any imaging sequence.

In the 2D multi-slice version, the prepulses were followed by a transient field echo block consisting of three EPI repetitions (TR=57ms), each including 13 echoes. Because the actual number of phase encoding steps was 39, one complete slice was acquired after each preparation phase. 12 slices were acquired sequentially in 3 seconds.

In the 3D TFE-EPI version, we acquired 15 slices, of which 12 were reconstructed. The prepulses (T2 preparation and SPIR) were followed by a transient field echo block consisting of five EPI repetitions (TR=57ms), each including 13 echoes (y encoding steps). Nine such cycles were acquired sequentially to complete one 3D scan (total duration: 3.9s). Hence z encoding steps were distributed inside blocks and between cycles.

In the 3D FFE-EPI version, we acquired 15 slices, of which 12 were reconstructed. The prepulses (T2 preparation and SPIR) were followed by one single EPI train including 21 echoes. The total acquisition time for one dynamic scan was 3.3s.

The stimulation protocol was : motor cortex activation (right hand cycling finger tapping), 100 dynamic scans, block design with a period of 20 dynamic acquisitions. Z-maps were computed on basis of a box-car waveform delayed by two dynamic scans with respect to the stimulation timing.

Results
Figure 1 shows the Z-maps (threshold Z=4) overlaid onto the original images, at two slice locations and for the 3 T2-prepared EPI acquisitions described above. The images are clearly T2-weighted (CSF is bright as compared with gray and white matter). The relatively high distortion level is characteristic for EPI acquisitions. Because Z threshold and total number of dynamic scans were identical for all 3 methods, the images show that 3D TFE-EPI provides the highest functional contrast-to-noise ratio (CNR), 2D TFE-EPI and 3D FFE-EPI being less efficient.

Discussion
This study demonstrates the feasibility of using T2-preparation in combination with GE-EPI in order to introduce an additional spin-echo BOLD component. The difference in CNR between 3D and 2D TFE-EPI could be due to the intrinsic improvement in signal-to-noise ratio with 3D scans. Another explanation for the differences observed could be the rate at which T2-preparation is applied : in the 3D FFE version it occurs before each and every EPI train (i.e. once every 110 ms) while in the 3D TFE version it occurs only once every 5 EPI trains (i.e. once every 420 ms) and in the 2D TFE even only once every 3000 ms; hence the management of longitudinal magnetization greatly differs from one sequence to the other. Also magnetization transfer effects could vary due to different RF deposition per unit time.

References
(1) P.A. Bandettini, E.C. Wong, A. Jesmanowicz, R.S. Hinks, J.S. Hyde. NMR in Biomedicine, 7, 12-20, 1994

Fig. 1 : Activation maps obtained with T2-prepared GE-EPI sequences : 2D TFE-EPI (upper), 3D TFE-EPI (middle), 3D FFE-EPI (lower). Threshold Z=4. Activated pixels are overlaid as hyperintense pixels onto the original images.