

## Two Embedded Techniques for Simultaneous Acquisition of Flow and BOLD Signals in Functional MRI

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**Purpose:** We present here two techniques that simultaneously measure flow weighted (1) and BOLD weighted (1-3) functional signals, and use them to map spatial variations in functional maps made with these two kinds of contrast. We use embedded techniques so that there can be no question of subject motion or subject variability between measurements.

**Methods: Hardware and Imaging:** Scanning was performed on a GE Signa 1.5T system fitted with a local three axis head gradient coil and a quadrature transmit-receive birdcage RF coil, both of our own design. Both techniques use single shot blipped EPI at  $64 \times 64$  resolution with a FOV of  $20\text{cm} \times 5\text{mm}$  as the imaging technique.

**Technique 1: Direct  $R2^*$  and  $M_0$  Mapping (4).** In this technique, we scan using gradient recalled EPI at a constant TR, but increment the TE by 5ms each shot from 35ms to 80ms, then back to 30ms throughout the timecourse. Sequential images were acquired in this manner for 10 minutes, with 2 epochs of bilateral finger tapping evenly spaced throughout the timecourse. The MR signal from each TE series was fit to a monoexponential decay, giving a  $R2^*$  and a  $M_0$ . The correlations between the timecourse of  $R2^*$  and  $M_0$  values and a reference function were used to generate contrast to noise ratio (CNR) maps for BOLD and flow sensitive functional signal changes, respectively. Three values of TR (500ms, 1000ms, and 3000ms) were used to manipulate the degree of flow sensitivity.

**Technique 2: BOLD Weighted EPISTAR.** In this technique, we use EPISTAR (5) to map perfusion changes, but use an asymmetrical spin echo imaging technique to incorporate BOLD contrast. Imaging parameters were: an inversion slab thickness of 10cm with a 1cm gap between inversion slab and imaging slice; inversion times of 400ms and 1200ms; TE was 80ms with a tau offset of -30ms; and TR was 3s. Perfusion changes were mapped by taking pairwise subtractions of even minus odd images, creating a time course of perfusion images, and CNR maps were calculated as above. BOLD CNR maps were calculated separately for the even and odd images, treating those as separate timecourses. In addition, these experiments were repeated with a small amount of diffusion weighting ( $b=10\text{s}/\text{mm}^2$ ) to destroy intra-arterial signal.

**Results:** CNR maps for Technique 1 are shown in Figure 2 and for Technique 2 in Figure 2. These were collected in one normal subject during one imaging session. From these preliminary data some general observations can be made: (1) Flow related and BOLD related functional changes can be monitored simultaneously and independently (this is seen in some of the images from Technique 1 where some pixels show flow related but not BOLD activations and vice versa). (2) EPISTAR perfusion changes are more localized and typically more medial than concurrent BOLD changes. (3) Inferior inversion of blood reduces the BOLD signal. This is prob-

ably due to inversion of venous blood which at that level in the brain is predominantly flowing superiorly, and indicates a large intravascular component to the BOLD signal. (4) Diffusion weighting attenuates the early TI functional perfusion signal more than the late TI signal, suggesting that the late TI functional perfusion signal is located in small vessels or brain parenchyma. (5) The  $\Delta M_0$  signal is more focal and more lateral than the majority of the EPISTAR perfusion signal, and therefore appears to be sensitive to a different aspect of flow.

**Conclusions:** For study of functional contrast mechanisms, embedded flow sensitive and BOLD sensitive pulse sequences make possible careful mapping of different aspects of functional signal changes without concern for misregistration of functional maps.

### References

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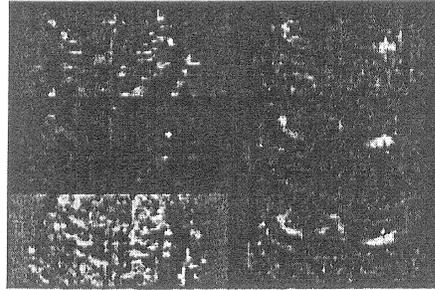


Figure 1 CNR maps from Technique 1. Left column is  $\Delta M_0$  maps, right column is  $\Delta R2^*$  maps. From Top to bottom: TR=500ms, 1000ms, 3000ms.

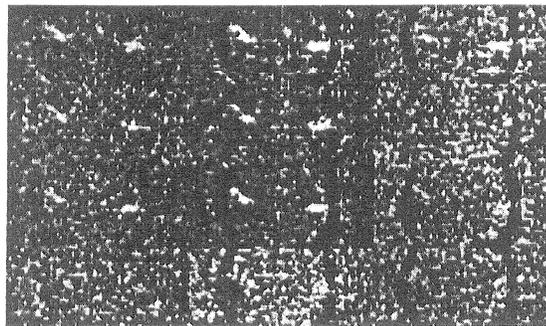


Figure 1 CNR maps from Technique 2. From left to right: EPISTAR perfusion; BOLD with superior inversion; BOLD with inferior inversion. From Top to bottom: TI=1200ms,  $b=0$ ; TI=1200ms,  $b=10\text{s}/\text{mm}^2$ ; TI=400ms,  $b=0$ ; TI=400ms,  $b=10\text{s}/\text{mm}^2$ .