

High Resolution Functional Perfusion and BOLD Imaging Using Q2TIPS, Half k-Space EPI, and Simultaneous Two-channel Acquisition

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Introduction: It is thought that the sites of functional perfusion and BOLD signal changes have different locations since the perfusion signal arises mostly from small arteries, capillaries, and brain tissue while the BOLD signal comes from capillaries, intracortical and pial veins, and tissue and cerebrospinal fluid surrounding intracortical and pial veins. Functional maps of perfusion and BOLD may show increasing differences with increased spatial resolution. It was shown that activation-induced perfusion changes, measured using EPSTAR and FAIR techniques (1, 2), are smaller and overlap with BOLD. It was also shown that using QUIPSS II (3) the largest BOLD changes were restricted to the sulcus while perfusion changes had a wider distribution. QUIPSS II is insensitive to transit delay and suitable for functional studies since transit delay is shorter during task state. Moreover QUIPSS II can be used to simultaneously acquire quantitative perfusion data and BOLD contrast data, and is amenable to multislice acquisition (4). In this study, we use a modified version of QUIPSS II: QUIPSS II with Thin-slice T_1 Periodic Saturation (Q2TIPS), which we describe in a separate abstract. This sequence has improved insensitivity to transit delay and also has a more precise tag bolus. For high spatial resolution and high signal-to-noise ratio (SNR) imaging, half k-space EPI (5) and simultaneous two-channel acquisition with a surface coil and quadrature birdcage coil were used.

Methods: All images were acquired using a 3T Bruker Biospec 30/60 scanner. A three-axis local head gradient coil was used. Simultaneous two-channel acquisition was used with an endcapped quadrature birdcage coil and a receive-only planar-pair surface coil placed inside. Single-shot blipped gradient echo half k-space EPI acquisition was used with 16 cm FOV, 8 mm slice thickness, and 128x128 matrix, equivalent to an in-plane resolution of 1.25 mm. For diffusion weighting studies, a bipolar gradient of 16 ms ($b = 1 \text{ sec/mm}^2$) was used. The PICORE tagging scheme was used with a 10 cm inversion tag and a 1 cm gap to the imaging slice. 2-cm T_1 saturation pulses located at the distal edge of the tagging region were applied from 0.7 sec to 1.1 sec at 50 ms intervals. TE was 12.6 ms and TR was 2.3 sec. Typically 720 repetitions were acquired with 46 sec on and 92 sec off finger tapping episodes. Perfusion time series were constructed by subtracting from each image the average of the immediately previous image and the next image. BOLD time series were obtained by adding to each image the average of the immediately previous and next images. Perfusion maps were generated by averaging the entire time series. Functional perfusion and BOLD images were created using cross-correlation with an ideal trapezoidal waveform. SNR measurement of the perfusion signal was performed at the motor cortex regions where functional responses were found for both the surface and birdcage coils.

Results: The measured SNR of the surface coil was 2.7 times higher than that of the birdcage coil. With simultaneous acquisition, the surface coil can be used to gain higher SNR in one hemisphere, while the birdcage coil can still acquire signal from the rest of the brain region with an uniform reception field. Fig. 1a shows an inversion recovery EPI image acquired at the nulling point of white matter. This is used as the anatomical reference. Averaged perfusion images obtained simultaneously using the surface coil and the birdcage coil are shown in Fig. 1b and 1c respectively. Only the perfusion image derived from the birdcage coil is a quantitative perfusion map. Fig. 2 shows the functional perfusion and BOLD maps from both left and right motor cortex.

All four maps were acquired simultaneously. The BOLD signal is confined in a narrow strip along the sulcus or the surface of the cortex, presumably coming mainly from the epicortical veins. The BOLD signal also tends to be more elongated and presumably more downstream than the perfusion signal changes. This supports the hypothesis that the perfusion signal changes are localized within the capillary bed while the BOLD signal might still be observed in the draining veins away from the activation sites. The largest BOLD signal changes correspond to large draining veins as revealed in the T_2^* weighted image (Fig. 1d). Perfusion signal changes are much more diffuse and distributed gray matter. However, large perfusion signal changes are also observed at the sites of draining veins. Fig. 3 shows the functional maps obtained with a small amount of diffusion weighting. The focal spots in the perfusion maps are diminished and those in the BOLD maps are also decreased.

Conclusions: At high resolution, the functional perfusion and BOLD maps, while showing much overlap, still show significant differences in shape, size, and relative magnitude distribution. A small amount of diffusion weighting is needed to minimize venous contribution.

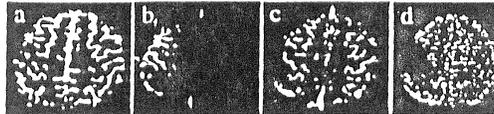


Figure 1. (a) Inversion recovery EPI image, averaged perfusion images obtained with (b) surface coil and (c) birdcage coil, and (d) T_2^* -weighted image.

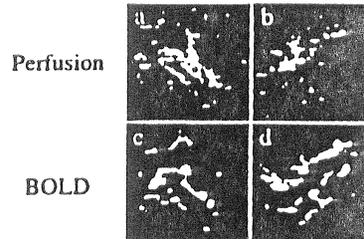


Figure 2. Functional perfusion and BOLD maps obtained simultaneously with (a, c) surface and (b, d) birdcage coils.

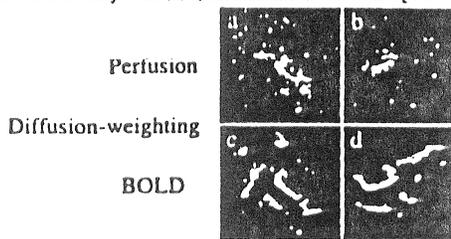


Figure 3. As in Fig. 2 but with diffusion-weighting.

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