A blood flow navigator for assessing physiologic noise in EPI data

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Introduction

It is well known that statistical power in fMRI experiments is reduced due to physiological noise in the BOLD time series collected with EPI. If independent measurements of cardiac and respiratory activity are available, the corresponding noise component in the time series can be reduced and the statistical power improved. One commonly used approach to doing this is RETROICOR [1] and the cardiac signal (photoplethysmograph) is typically observed using a pulse oximeter or ECG.

We present an alternative method of observing the cardiac signal using a single slice EPI navigator positioned at the level of the neck. Even if velocity and/or phase contrast are not explicitly encoded, several pixels in the image of the neck that correspond to the vertebral and carotid arteries reflect blood flow dynamics when the images are acquired in rapid succession.

The navigator approach negates the need for an additional sensor and cables in the scanner that may present a small safety risk to the subject, especially at high field strengths. Also, the blood flow information from the navigator is more tightly coupled to the flow of blood in the brain and may therefore be a better regressor for removing the associated noise.

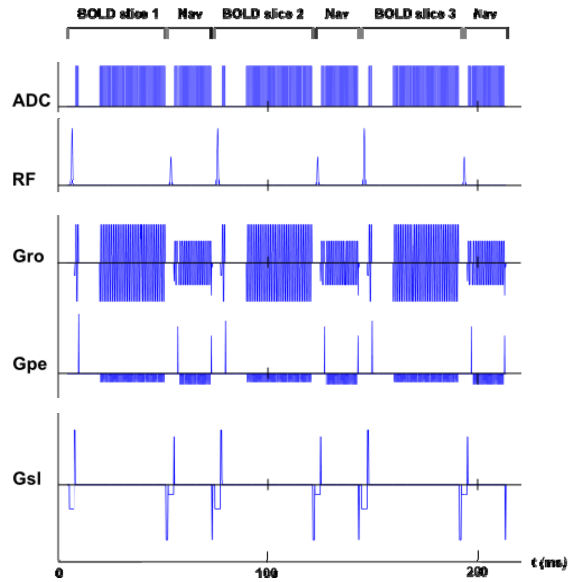

Figure 1: Pulse sequence diagram for interleaved multislice BOLD EPI and single slice EPI navigator for observing blood flow in the neck.

Methods

Figure 1 illustrates the first 214 ms of the pulse sequence used in this experiment. A single slice gradient echo EPI neck navigator is inserted between each slice of the multislice gradient echo BOLD EPI sequence. The sequence was implemented on a 1.5 T Siemens (Erlangen, Germany) Avanto scanner with a parallel reconstruction pipeline to reconstruct both image series during the scan. Imaging parameters for BOLD EPI were: TR 2 s, TE 30 ms, 28 x 4 mm slices separated by 1 mm, FoV 210 mm (64x64), FA 90°, BW 2298 Hz/px. Parameters for the navigator were: duration 24 ms, TE 12 ms, 10 mm slice, FoV 165 mm (32x32), FA 45°, BW 2298 Hz/px. The effective TR (time between excitations) for the navigator was 71.4 ms (2 s / 28). The navigator was positioned at the level of the neck just below the chin and an example image is shown in Figure 2.

We collected a 4 minute scan (120 measurements) using the above protocol with a subject performing finger tapping with the right hand during 30 s on-off blocks. Blood flow in the middle finger of the left hand was measured with a pulse oximeter.

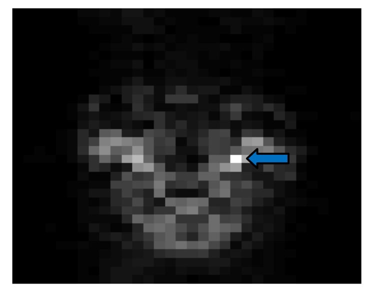

Figure 2: Example EPI navigator from neck. Left arterial voxel is marked.

Results and Discussion

Figure 3 (top) illustrates the time course obtained from an arterial voxel in the navigator (normalized intensity of voxel identified in Figure 2). We used Melodic [2] to obtain 3 independent components of the navigator slice series. The 2nd component explained 13% of the signal variance and is shown in Figure 3 (bottom). The other two components also showed strong cardiac synchrony and together explain 40% of the signal variance. This illustrates that the cardiac signal can be easily and automatically extracted.

To examine the relationship between the EPI time series and the cardiac signal measured via the neck navigator, a general linear model was fit to each EPI slice individually. Within-slice spatial smoothing (6.5^2 mm^2 FWHM) was applied to boost SNR while maintaining the temporal sampling particular to the slice. After this, each voxel in the slice was fit to a model that included regressors to account for finger-tapping related neural activation as well as the measured neck navigator time series. The neck navigator time series regressor was low-pass filtered with a cutoff of 0.36 s to account for time series noise and potential flow delay between the neck and brain. Finger tapping activation maps and cardiac signal maps were produced by computing voxel-wise *t*-statistics from their corresponding model parameters. As expected, a strong activation was observed in left motor cortex and in right cerebellum from the finger tapping task. There was very little effect of the cardiac signal in these regions, but there was a strong cardiac-related signal in the ventricles, near the midbrain, and near the sagittal sinus (Figure 4).

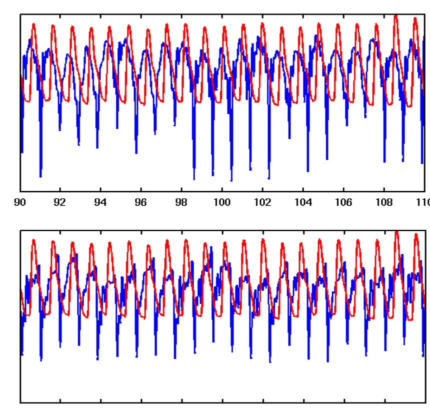

Figure 3: Time course of navigator arterial voxel (top, blue) and time course of 2nd independent navigator component (bottom, blue). Photoplethysmograph is red.

The blood flow navigator reliably monitors blood flow in major neck arteries in real-time during imaging without requiring monitoring equipment in the scanner. The information is tightly coupled to blood flow in the brain and could be used, for example, to correct resting-state functional data.

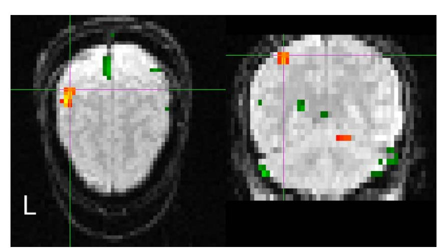

Figure 4: Finger-tapping activation (red) and voxels with cardiac-related signal (green).

Acknowledgments

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References

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