Noise characteristics of arterial spin labeling fMRI using spiral SENSE at 3T

J. E. Perthen[1], M. Bydder[2], K. Restom[1], T. T. Liu[1]

[1]Center for Functional MRI, UCSD, San DIego, CA, United States, [2]Radiology, UCSD, San DIego, CA, United States

Introduction

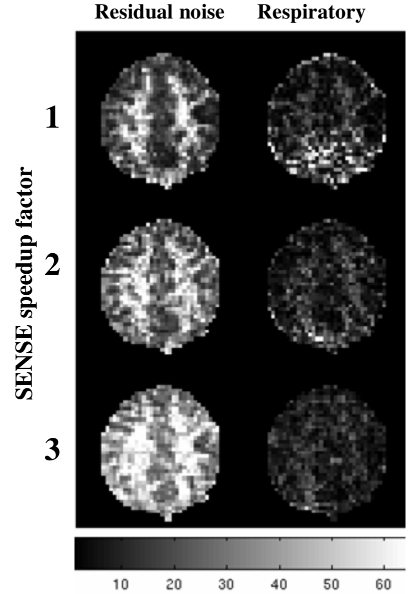
Arterial spin labelling (ASL) functional MRI (fMRI) is finding greater use, in part because the perfusion signal may be a more accurate reflection of neural activity than the commonly used blood oxygenation level dependent (BOLD) signal. These studies are increasingly being performed at 3T, where the higher field strength and the longer T1 of blood aid in increasing SNR. In addition, the application of parallel imaging to ASL is growing because of the advantages of a shorter readout window (e.g. reduced susceptibility-related artifacts, potential for shorter echo time) [1].

It has previously been reported that physiological noise dominates thermal and scanner noise at 3T [2], and that removing the physiological noise components from perfusion fMRI data can lead to large increases in SNR [3]. In this study, the effect of parallel imaging on the noise characteristics of ASL fMRI data is investigated using data acquired with SENSE factors 1, 2 and 3 [4], achieved by shortening of the readout window. A good understanding of the noise components is crucial in a technique with inherently poor SNR such as ASL. Since physiological noise contributions have been shown to depend upon TE [2], this confounding factor is removed by using a spiral acquisition, such that images acquired at all SENSE factors have identical TE.

Methods

Scanning was performed on a 3T GE Signa whole body system, with a transmit body coil and an 8 channel receive only head coil. A PICORE QUIPSS II [5] sequence was used with a gradient echo spiral readout. Imaging parameters were: TR=2s, TI1=600ms, TI2=1500ms, $\theta = 90°$, FOV = 24×24cm, matrix size 64×64, TE=9.1ms, with four 7mm slices positioned through the primary visual cortex at an oblique angle parallel to the calcarine sulcus. Three functional runs were acquired whilst viewing a radial checkerboard flashing at 8 Hz that was presented in a block design paradigm (4 cycles of 20s stimulation and 40s rest, beginning with 40s rest). Cardiac pulse and respiratory effort data were recorded continuously. One functional run was acquired with full sampling of k-space (SENSE factor 1), one with SENSE factor 2, and one with SENSE factor 3.

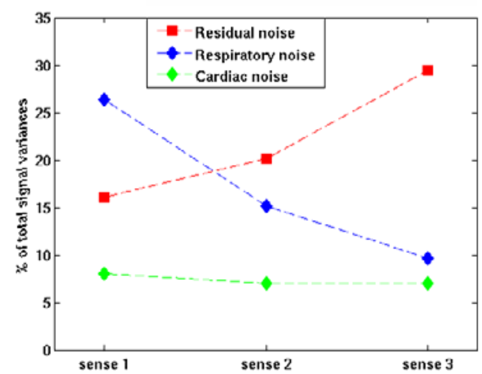
For each functional run, a perfusion time series was created using a running subtraction, and modeled using a general linear model (GLM) with physiological noise regressors [6]. The % of the total signal variances explained by the functional activation, respiratory noise, cardiac noise, and residual noise components were calculated. In order to compare the effect of different acquisitions on the ability to detect the functional activation, an F-statistic was calculated from the GLM. The mean F-statistic for voxels above a threshold of 25 (corresponding to correlation coefficient = 0.4) were calculated before and after physiological components were removed.



Results

The figure shows the spatial distribution of the respiratory and residual noise components, expressed as a percentage of the total energy in the perfusion time series, for increasing SENSE factors. The residual noise is a larger percentage of the white matter signal, since the mean signal intensity is lower here than in gray matter. The residual noise component increases with SENSE factor, since fewer samples of k-space are acquired. The respiratory component is larger towards the posterior part of the brain, and decreases with increasing SENSE factor. The cardiac component (not shown) is a small contribution and shows no dependence upon SENSE factor.

The graph shows the signal components within activated voxels in the visual cortex. Physiological components dominate over other noise sources for SENSE 1, but their overall contribution decreases as SENSE factor increases, due to the decrease in respiratory noise. The mean F-statistic for correlated voxels was found to be comparable between the three SENSE acquisitions before removal of physiological terms. However, physiological correction was found to be of most benefit for lower SENSE factors: the increase in the mean F-statistic for all voxels exceeding the threshold F=25 was **21%** for SENSE 1 (mean F before = 55, after = 67, $p<0.002$), **16%** for SENSE 2 (mean F before = 47, after = 54, $p<0.005$), and **5%** for SENSE 3 (mean F before = 49, after = 51, p=0.4).



Discussion

The use of SENSE in ASL fMRI changes the contribution of the noise components to the perfusion time series. In general, the contribution of respiratory noise decreases as the length of the acquisition window shortens, possibly reflecting the fact that there is less time for accrual of global phase errors induced by the expansion and contraction of the thoracic cavity. As expected, the residual noise (primarily thermal noise) increases as the readout window shortens. Functional data show that in areas of the brain contaminated by respiratory noise, the removal of physiological noise components gives the largest improvement in SNR when using long readout windows (low SENSE factors). In conclusion, if physiological components are measured and removed from the ASL fMRI signal, full sampling of k-space is optimal. However, if these components are not removed, use of a speedup factor may be appropriate for the reduction of artifacts, without a significant loss in functional sensitivity.

References

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