FMRI ACQUISITION STRATAGIES

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•Simultaneous multi-slice (SMS) or multiband (MB) MRI increases slice coverage or reduces TR in FMRI
•Controlled Aliasing with CAIPIRINHIA (2) and blipped-CAIPI (3) improves image quality and SNR by reducing g-factor.
•Zoomed Imaging achieves ultra-high (sub-millimeter) resolution in fMRI with reduced FOV.
•3D FMRI can be performed with trade-offs between coverage and speed.

Multi-slice 2D EPI

Echo planar imaging (EPI) is the most commonly used imaging sequence for fMRI due to several factors. First, there is a high degree of BOLD sensitivity in the gradient echo train with its T2* contrast. Second, all signal contributing to each image slice is from a single echo train with similar cardiac phase which prevents physiological artifacts arising from CSF motion. Third, the multi-slice EPI acquisition achieves a very high efficiency in terms of image SNR per acquisition time. To date, gradient echo (GE) EPI is the mainstay of fMRI experiments at 1.5T and 3T field strength

High Speed 2D FMRI Sequences

Simultaneous Multi-Slice (SMS) EPI which is also called Multiband (MB) EPI, (1-6) has recently become useful for fMRI through technical innovations and undergoing improvements in g-factor for higher SNR. Improved separation of slices and dealiasing using blipped-CAIPI (3) has allowed much higher slice acceleration factors. The spatial heterogeneity of g-factor must be considered in studies (3, 6) . Unlike in-plane acceleration by parallel imaging, SMS EPI does not reduce the echo train length therefore SNR is not reduced, and SMS instead reads out slices simultaneously in the echo train to increase slice coverage or reduce TR for greater sampling speed (4,5). At 7T the MB EPI has been advantageous used to reduce slice thickness to reduce Bo inhomogeneity signal losses while performing whole brain fMRI without prohibitively long TR (3). In resting state connectivity fMRI the use of SMS EPI to scan much faster, reducing TR to subsecond range, to improve the statistical definition of networks and generally provided richer information on resting state connectivity (5).

3D FMRI sequences

Single-shot 3D imaging techniques for fMRI have also undergone a phase of rapid improvement (11-13). The Inverse Imaging technique has recently been improved with blipped-CAIPI controlled aliasing. The 3D EVI sequence has undergone many k-space trajectory optimizations using spiral and parallel imaging approaches. The limitations of susceptibility artifacts and spatial resolution appear to be greatly mitigated by these optimizations of single-shot 3D techniques.

High Spatial Resolution FMRI

The ultra-high field scanners, 7 Tesla and higher, have become a platform for pushing spatial resolution limits for fMRI in order to explore function specific organization in cortical regions and to study differential layer specific activity in cortical laminae (7-10, 13). Inner volume imaging techniques also known as Zoomed EPI is powerful for achieving sub-millimeter resolution in brain sub-regions by means of avoiding aliasing artifact of overlapped brain regions. Several different approaches to zoomed imaging (inner volume, outer volume suppression, 2D-selective excitations) all share in common that matrix size is held constant while FOV is reduced to reciprocally increase spatial resolution. The inner volume 3D GRASE sequence has allowed acquisition of several slices while zoomed SE-EPI can only achieve a single slice. Further advantages of GRASE includes stimulated echo signal which has longer T1 decay than T2 or T2* decay. The relative weighting between small vessel BOLD signal vs large vessel and draining vein are dependent on the imaging sequence contrast mechnisms of GE, SE and STE signals. Optimization of the Zoomed imaging sequences for SNR, resolution, volumetric coverage and sampling speed, and sensitivity to physiological noise, all become important for fMRI at 7T. Also promising for cortical resolution imaging, highly accelerated 3D EPI using segmented (multi-shot) sequences and highly accelerated SMS-EPI sequences are beginning to achieve submillimeter resolutions.

In conclusion, recent generalization of simultaneous multi-slice to multi-volume imaging and generalized improvements in image reconstruction utilizing controlled aliasing to improve image SNR represent the current phase of improving acquisition strategies. The use of zoomed imaging for high resolution fMRI and SMS EPI and 3D techniques for faster sampling rates, are current approaches to push the boundaries of speed and resolution in fMRI.

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