Real-Time Multi-Shot EPI for Whole Brain FMRI

R. Zhang[1], H. Lu[1], V. Roopchansingh[1], A. Jesmanowicz[1]
[1]Medical College of Wisconsin, Milwaukee, WI, United States

Synopsis: A real-time multi-shot EPI method is presented. This method will facilitate high-resolution functional MRI and diffusion tensor imaging. Multi-shot (or segmented) EPI acquisition provides high spatial and temporal resolution without sacrificing signal intensity or *k*-space coverage. Real-time acquisition and reconstruction enables data quality monitoring, and allows for interactive development of functional paradigms. Combined with real-time motion correction and functional analysis by the AFNI software package, this method provides a means for efficient and accurate functional studies.

Introduction: The single-shot EPI method has been widely used in functional MRI (fMRI) studies. The matrix size commonly used for single-shot EPI is 64 × 64, but higher resolutions are usually desired to depict functional details. However, higher matrix sizes are usually not used with single-shot full *k*-space EPI, due to signal decay resulting from the long TE required by the long acquisition time. In diffusion tensor imaging (DTI), where TE is already prolonged by the diffusion gradients, single-shot EPI at high resolution becomes impractical. Multi-shot EPI has been introduced for high resolution fMRI and DTI [1]. A challenge with this technique, however, is the ghosting artifacts resulting from motion, due to the phase errors among segments of *k*-space that are acquired at different times. Although post-processing correction methods for multi-shot EPI have been developed [2], when the errors are too large to be corrected, the data are usually discarded. An efficient way to avoid motion-related data corruption is to re-acquire data as soon as the problem becomes visible. To the best of our knowledge, there are no published reports on dynamic monitoring of data quality during segmented EPI acquisition. Here we have implemented real-time segmented EPI data acquisition and reconstruction as an extension of the real-time single-shot EPI method [3].

Methods: Pulse programs were implemented on a Bruker Biospec 3T/60 system. Experiments were performed using a torque-balanced local head-gradient coil and an end-capped birdcage RF coil. A 165 mm diameter grid phantom was used in the preliminary studies. The RF signal from the scanner was directed to an SGI R10000 Challenge computer equipped with an Analogic 16-bit ADC4322 A/D converter. At the beginning of each time series, a set of phase-encoded reference scans was collected and saved in memory [4]. Navigator-echoes were collected for each k-space segment. Data from each segment were phase-corrected as they were acquired, using the reference scan to reduce ghosting artifacts resulting from *k*-space misalignment. If the phase error exceeded a preset threshold, the operator was prompted and given an option to interrupt the scan. Otherwise, each slice was reconstructed immediately after all segments of *k*-space were filled, and the image was displayed in real-time. Images were also sent to the AFNI program for real-time functional analysis [5,6]. A flow chart of this process is shown in Fig. 1.

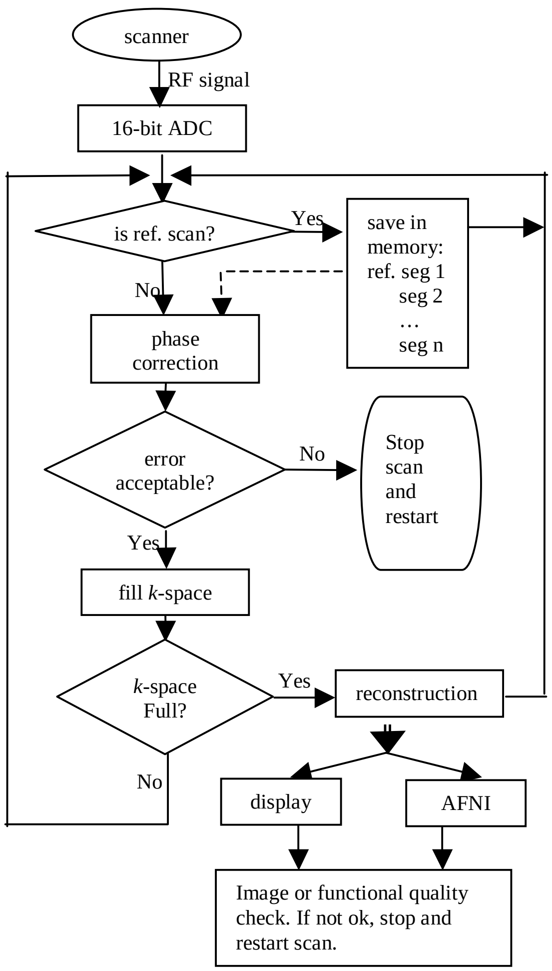
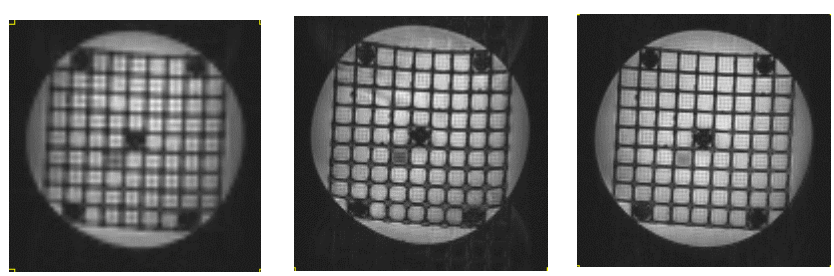


Fig. 1. Flow chart of real-time multi-shot EPI acquisition and reconstruction.

Results: Figures 2a-c show single-shot 64 × 64, single-shot 128 × 128, and two-shot 128 × 128 EPI images. All images were acquired using gradient-echo EPI, under the same shim condition, with FOV = 20 cm, TR = 1000 ms. TE was 40 ms for (a) and (c), but the minimum TE of 67 ms was used for (b).

Conclusion and Discussion: The real-time multi-shot EPI method allows high resolution data acquisition without compromising TE or *k*-space coverage while making it possible to monitor image quality as data are collected. The images acquired with two shots show less artifacts and distortion than those with single-shot EPI at the same resolution. During the real-time process, when the error in the data is not correctable by data processing, this method permits stopping the experiment and re-acquiring the data sets immediately. This is important for fMRI and diffusion tensor imaging, where one set of suboptimal data may render the entire experiment unusable. Re-acquisition may potentially be automated for specific paradigms, eliminating operator intervention. Combined with real-time motion correction and functional analysis by the AFNI software, this method provides a means for real-time whole brain fMRI at higher spatial resolutions with high SNR at full *k*-space coverage.

References: 1) McKinnon GC, *Magn. Reson. Med.* 30:609-616; 2) Butts K, *et al.*, *Magn. Reson. Med.* 35:763-700; 3) Cox RW, and Jesmanowicz A, *ISMRM 1998*, p.295; 4) Lu H, *et al.*, *ISMRM 2002*, p.2372; 5) Cox RW, *Comput. Biomed. Res.* 29:162-173; 6) Cox RW, *et al.*, *Magn. Reson. Med.* 33:230-236.



(a) (b) (c)

Fig. 2. Comparison of images with single- and multi-shot EPI acquisitions. (a) single-shot, 64× 64, TE = 40 ms. (b) single-shot, 128 ×128, TE = 67 ms. (c) two-shot, 128 × 128 matrix, TE = 40 ms.