MRI Signal Stability in a Phantom

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INTRODUCTION

Functional magnetic resonance imaging (fMRI), dynamic contrast injection imaging, and other techniques for which many images are acquired rapidly in a time series place increasing demands on the stability of MRI scanners. Many of these techniques assume that each image will differ only in the specific effect of interest, such as BOLD contrast in fMRI. In the case of BOLD contrast, these changes typically involve 0.1 to 2.0 percent changes. If the MR system fluctuates more than this from image to image, the ability to extract the desired signal can be seriously compromised. The purpose of this study is to carefully characterize the stability of several MR systems within the time frame of a typical fMRI study such that the effect of these changes can be evaluated.

METHODS

The stability of four 1.5T MR imaging systems was assessed using the following protocol. Multiphase interleaved single-shot gradient-echo echo-planar imaging (TE/TR/Flip = 50 ms/3000 ms/90°) was performed on 1.5 T MR imaging systems using the systems' standard quadrature RF volume head coils. Three systems were GE Signa Horizon Echo Speed 5.6 (GE Medical Systems, Milwaukee, WI) with 23 mT/m gradient systems (SR=120mT/m/ms). The fourth system was a GE Signa LX 8.2.5 NVi (GE Medical Systems, Milwaukee, WI) with 40 mT/m gradient systems (SR = 150 mT/m/ms). Additional imaging parameters were: field-of-view = 40 x 20 cm, matrix = 128 x 64, full bandwidth = 360 kHz, and six contiguous 7 mm slices. A locally constructed 10 cm diameter spherical gel phantom (2% agar, 0.01% azide) was used in all imaging. Six runs of 80 phases per slice (4 minutes) were acquired with a one minute pause between each run. A four minute run with six slices was chosen to simulate a typical fMRI run within the limit of 512 images in a run using the standard echo-planar pulse sequence. No prescan settings were changed between runs.

Data was analyzed using MATLAB (Mathworks, Natick, MA). The first three time points in each run had not reached spin equilibrium thus were disregarded in the analysis. Five 36 voxel square regions of interest (ROI) were selected in each slice. One ROI was placed in the center of each image and the remaining four ROIs were distributed around the center ROI. The time course of the mean signal was calculated for each of these ROIs and also for the entire phantom in each slice. A first order linear regression of signal intensity vs. time was also calculated for every voxel in all images. The mean slope was calculated for each region of interest.

RESULTS

Figure 1 is a graph of the percent change in signal intensity over time for one slice from one MR system. All of the systems tested showed a systematic decrease in signal intensity during the imaging session. The magnitude of this decrease was consistent among the ROIs in a slice across runs. However, the magnitude of the percent decrease varied between slices. Analysis of the mean intensity of the phantom in each slice revealed that each slice had mean signal intensities varying up to 20% from the mean signal of the volume. Within a slice, the total signal decrease from the start of the first run to the end of the last run ranged from 0.3% to 1.0%. The magnitude of the decrease within a slice was consistent across slices on a MR system. The mean of the standard deviation of the percent signal change in each run was 0.07 percent signal change. As seen in runs 1 and 4 in Figure 1 (arrows), rapid shifts in signal intensity occurred within runs. The signal intensity dropped 0.2% to 0.3% in 9 to 12 seconds and remained at the shifted baseline for 6-24 seconds before returning to the previous mean. Similar transient shifts occurred on all systems.

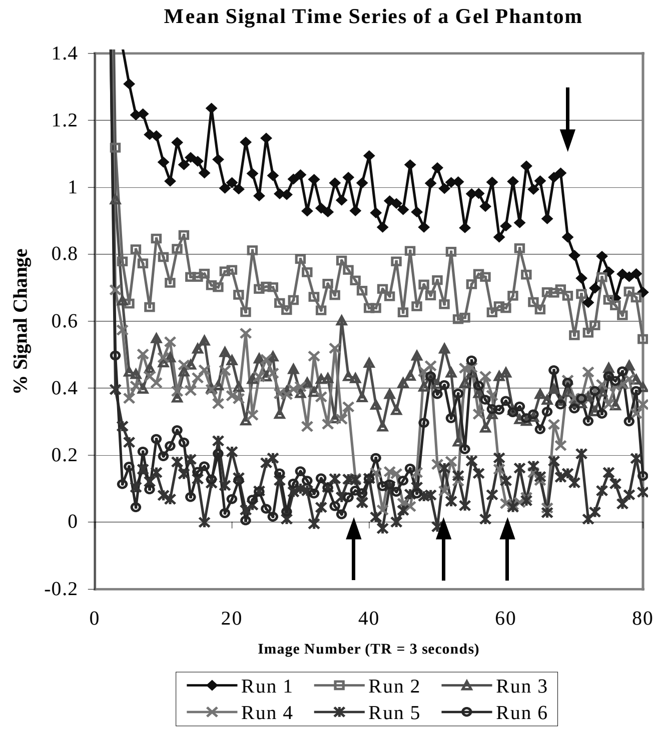

Figure 1: Mean Signal Time Series in a gel phantom in slice 5 on a single MR system

DISCUSSION

A number of techniques exist to remove slow changes in the signal intensity. The regional homogeneity of these changes within a slice suggest that techniques that calculate the system drift using averages within a slice may be effective. However, the observed variation between slices suggests that investigators use caution when calculating system drift using multiple slices. The transient shifts are more disconcerting because they add variance to the signal that cannot be easily removed because this noise has a form quite similar to a typical hemodynamic response. These transient changes in baseline may present particularly significant challenges in event related fMRI designs. Associated investigation of the stability of a single system revealed that stability was also duty cycle dependent (unpublished data). Additional investigation of the stability of MR systems may provide valuable information for system maintenance and data processing considerations.

REFERENCES

1. Smith, A.M. et al., *Neuroimage*, **9**(5):526, 1999.