The Efficacy of Cardiac Gating with Variable TR Correction in fMRI

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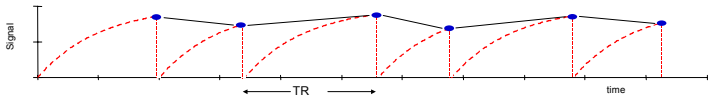


A variable TR (due to variations in the subject's heart rate) leads to fluctuations in the signal due to varying T1 saturation

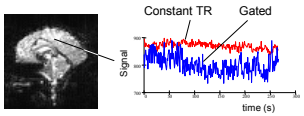
Introduction

Temporal signal fluctuations due to cardiac pulsations have shown to be significant in functional magnetic resonance imaging (fMRI), particularly at the base of the brain (1). With cardiac gating, images are acquired at the same phase of the cardiac cycle, ensuring that the images are precisely registered. The variability in heart rate results in a variable TR. This leads to large signal variations due to varying T1 saturation occur and must be corrected.

A gating and correction scheme has been shown by Guimaraes et al (2) to be feasible in reducing cardiac noise and improving the imaging of subcortical regions. This technique, however, has not been widely adopted for fMRI studies, relying instead on long TRs, signal averaging, flow compensation, and spatial saturation pulses (3). This is possibly due to the additional processing required to reduce the effects of the variable TR, a lack of information on the relative magnitude of cardiac noise, and an uncertainty in how accurately the signal variations due to the variable TR can be corrected.

The purpose of this study is to evaluate the effectiveness of correcting signal fluctuations due to the variable TR in gated fMRI studies.

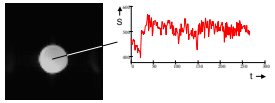
Two methods of correction are compared – 1) estimating T1 and M0 from the data, and 2) estimating T1 and M0 from a separate inversion recovery scan



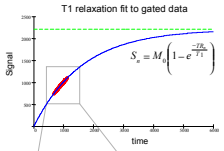
Triggering the acquisition off the heart beat results in a variable TR, leading to large variations in the signal.

(Acquisition of images was triggered off each heart beat in this study using a pulse oximeter.)

The Correction

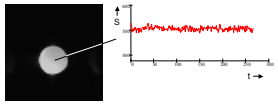


One (or more) single-shot EPI image is acquired at each heart beat. The TR for each acquired image is recorded.



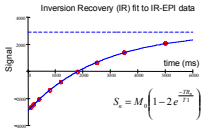
The signal is sorted according to the TR, and a T1 relaxation curve is fit to the data.

The fit is then removed. The signal at each point is adjusted to the value it would have had at the mean TR. (2)

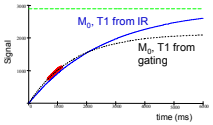


Signal fluctuations due to the variable TR are substantially reduced after correction.

Alternative Correction

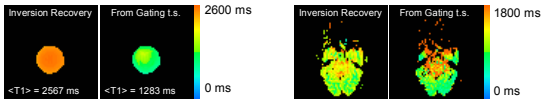


The T1 and M0 are estimated at each voxel by acquiring several inversion recovery (IR) EPI images at different inversion times (TI), and fitting an IR curve to the data.

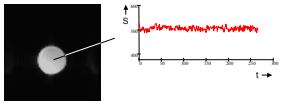


The relaxation (saturation recovery) curve generated using the T1 and M0 from the IR data (blue line) does not match the data from the variable TR time course (red).

T1 maps

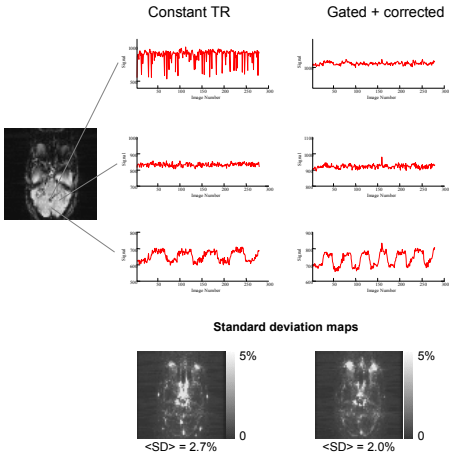


The T1 and M0 (not shown) maps are different depending on how the parameters are estimated. This is possibly due to contributions from previous echoes or flip angles different from 90°.



In some cases, the slope of the saturation recovery curve is similar over the range of TR's in the gating, allowing for correction of signal fluctuations.

How well does the correction work?



Methods

Axial images triggered using pulse oximeter.
280 EPI images, 64x64
Mean gated TR: 1439ms
Constant TR: 1000ms
TE: 30ms
3T GE Signa
24cm FOV, 5mm. sl.,

In some regions, cardiac gating considerably reduces signal fluctuations. In other regions, no significant difference is seen.

The standard deviation is reduced by cardiac gating with variable TR correction in certain areas.

Residual variance after correction

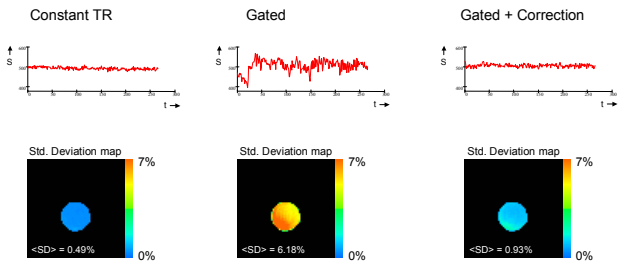
Methods

Pure H2O phantom
Gated using volunteer seated outside magnet
270 EPI images, 64x64
Mean gated TR: 943ms
Constant TR: 900ms
3T GE Signa
24cm FOV, 5mm. sl., TE: 30ms

Sources of variance:

- Errors in T1 and M0 maps
- Inaccurate triggering
- Inaccurate recording of TR's
- Incomplete signal model

Cardiac gating with variable TR correction slightly increases the noise (0.49% → 0.93%). Signal variations due to varying TR without correction are substantial (6.18%) for an average TR of 943ms in a pure H_2O phantom.



Conclusions

- Large signal variations due to cardiac pulsations are substantially reduced in certain regions
- Residual variance in signal time course is slightly increased by gating with correction.
- T1 and M0 maps estimated from the variable TR time course and from the IR data are different.
- Estimating the T1 and M0 from the variable TR time course to use for correction generally results in better correction of signal fluctuations due to varying TR.

References

1. B. Poncelet, et al., Radiology, 185 (3), 645-51, 1992.
2. A.R. Guimaraes, et al., Human Brain Mapping, 6, 33-41, 1998.
3. P.W. Stroman et al., Magn. Res. Med., 42, 571-6, 1999.

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