Image Reconstruction Scheme for Dynamic Perfusion Myocardium MRI Study

E. G. Kholmovski[1], P. Vemuri[1], E. V. Di Bella[1]

[1]UCAIR, Radiology, University of Utah, Salt Lake City, Utah, United States

Introduction

Dynamic myocardial perfusion MRI studies are widely used to detect perfusion deficit of myocardium. Typically the image quality of these studies is acceptable for a qualitative analysis but not good enough for a quantitative analysis such as estimation of absolute myocardial blood flow, washin and washout time characteristics. For a reliable evaluation of these parameters, improvement of image SNR and elimination of possible sources of systematic errors such as a bias in magnitude reconstructed MRI images are required. To partially solve these problems in dynamic perfusion MRI studies a novel reconstruction method combined with anisotropic diffusion filtering in spatial-temporal domain has been developed.

Theory and Methods

Image SNR can be improved by applying various filtering techniques such as anisotropic diffision filtering [1], Weiner filtering, and so on. However, the majority of them are optimized for processing images contaminated by zero-mean Gaussian noise uniformly distributed in image space. Assumption about Gaussion nature of noise is violated for magnitude reconstructed MRI images and for MRI images reconstructed from multicoil data by the sum-of-squares (SoS) technique [2]. Additionally, the noise distribution is spatially non-uniform in the SoS reconstructed images. Therefore, for optimal noise filtering either filtering technique should be optimized to image noise properties or image reconstruction scheme should be implemented in such a way that post-reconstruction image filtering is optimal. In this study, we exploit the second approach. A image reconstruction scheme has been developed which creates images from multicoil data of dynamic perfusion study with optimal noise properties for anisotropic diffusion filtering.

The proposed image reconstruction scheme is based on uniform noise reconstruction technique for multicoil data proposed by Roemer et al [2]. Our reconstruction scheme is formulated as follows:

$$I_\alpha(n) = \mathrm{Real}\left(\frac{I^T(n)\Psi^{-1}\Lambda^*(n-1)}{\sqrt{\Lambda^T(n-1)\Psi^{-1}\Lambda^*(n-1)}} \right)$$

where $I_a(n)$ is the reconstructed image for time frame n, $I(n)$ is a vector composed from individual coil complex images acquired for time frame n, Ψ is the noise correlation matrix, $\Lambda(n\text{-}1)$ is a vector of coil sensitivities estimates calculated using the previous time frame (n-1) coil images. The coil sensitivity estimates are recalculated for each time frame by the method proposed in [3]. Estimation of coil sensitivies from the previous time frame data is used to completely decorrelate noise in $I(n)$ and $\Lambda(n\text{-}1)$ resulting in the reconstructed images with noise described by zero-mean Gaussian distribution. The resulting images should have zero bias and optimal properties for filtering.

Results

All imaging studies were done on a 1.5T SIGNA Lx 8.4 scanner (GE Medical Systems, Milwaukee, WI) with NV/CVi gradients using a fast gradient echo pulse sequence with echo-plane readout and notch saturation pulse [4]. Acquisition parameters were: TR/TE=6.5/1.5 msec, Rbw=+/- 125 kHz, ETL=4, flip angle=20, FOV=280x210 mm, acquisition matrix=128x96, 7 slices, 8.0 mm slice thickness, 50 time frames. A cardiac phased array comprised of 4 coils was used. Raw data were saved for off-line reconstruction and post-processing.

Figure 1 shows the intensity distribution in tissue-free areas for the images reconstructed by the standard SoS technique and the proposed reconstruction technique. The plots indicate the existence of non-zero bias in SoS images and complete elimination of the bias in the images reconstructed by our new technique. Additionally, noise in these images can be described by zero-mean Gaussian distribution. Therefore, the proposed technique can be used to reconstruct the images with optimal noise characteristics for filtering. The reconstructed images were post-processed using spatial-temporal anisotropic diffusion filter. The filtering parameters were the following: 4 iterations, κ=1.5σ, where σ was estimated from tissue-free area of the reconstructed image. Filtering results are presented in Figure 2.

Discussion

A novel image reconstruction scheme for dynamic perfusion MRI data acquired by multicoil phase arrays has been developed. The resulting images have spatially uniform noise distribution and image noise is characterized by Gaussian distribution. Such images are optimized for application of various image filtering techniques such as anisotropic diffusion filters, total variation filter, and so on.

Acknowledgements

This work was supported in part by NIH grant R01 HL48223 and HL57990.

References

[1] Perona P, et al., IEEE PAMI 1990; 12:629-639
[2] Roemer PB, et al., MRM 1990;16:192-225.
[3] Bydder M, et al., MRM 2002;47:539-548.
[4] Slavin GS, et al., Radiology 2001;219:258-263.

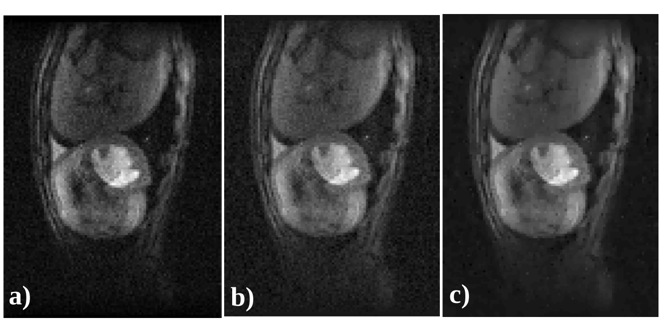

Figure 2. Image from dynamic perfusion myocardium study reconstructed by **(a)** SoS algorithm, **(b)** the proposed reconstruction technique. **(c)** Image of (b) after anisotropic diffusion filtering.

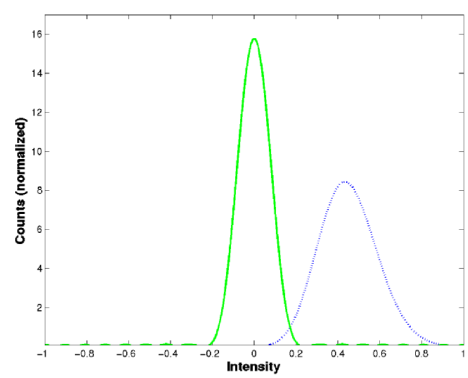

Figure 1. The intensity distribution in tissue-free areas for the images reconstructed by the standard SoS technique (dotted line) and the proposed reconstruction technique (solid line).