Proton Perfusion Maps from Time Series of the Pulmonary Vasculature

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Target Audience: Pulmonary MRI researchers and clinicians.

Purpose: Traditionally, Gd contrast agents have been used to provide wash-in/wash-out contrast in order to measure pulmonary perfusion (Q) with ^{1}H MRI. Recently, however, there has been a resurgence of interest in imaging the lung utilizing quickly acquired time series of images such as the Fourier decomposition (FD) method [1]. Here we examine several analysis methods that use simple statistical quantities to compute a Q map and we compare these Q maps to a Fourier component map. To remove the confounding effect of breathing, this study was performed with breath-hold images. Here we demonstrate that the harmonic components of the vascular waveform are significant and therefore Q maps can be improved when considering more than just the variation at the heartbeat. Additionally, we demonstrate that the mean of a time series produces similar or better Q maps as FD.

Methods: Coronal 2D TurboFLASH breath-hold scans were performed on 4 healthy subjects on a Siemens 3T Skyra. TurboFLASH parameters were TE/TR=0.8/202ms, FOV=350mm, data matrix=128x128 (interpolated to 256x256), turbo factor=116, $\alpha=20^{o}$, 8mm slice. Blood flow (Q) maps were calculated in three ways. A map of the Fourier component at the heart rate frequency was determined by integrating the spectrum around a small frequency interval about the heart rate frequency. In addition, the mean and standard deviation (STD) of the signal intensity were used to calculate Q maps. Spatial registration was not necessary as data was acquired during a breath-hold. To obtain harmonic spectra data, the TurboFLASH method was modified to have a temporal resolution of ~10 frames/s: TE/TR of 1.1/98ms, data matrix of 96x72, 4mm slice.

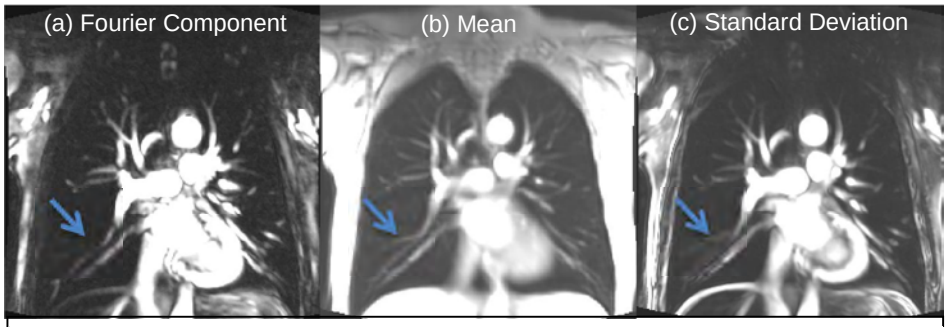

Figure 1. Q maps from a single breath-hold acquisition: (a) Fourier component at heart rate frequency, (b) mean signal intensity, and (c) standard deviation of time series. Arrows show missed blood vessels in (a).

Results: Figure 1 shows three different analyses from a single data set to create three Q maps. Figure 2 shows an example of the time dependent signal and the harmonic spectrum from an ROI (~10mm diam) in the anterior segmental pulmonary artery.

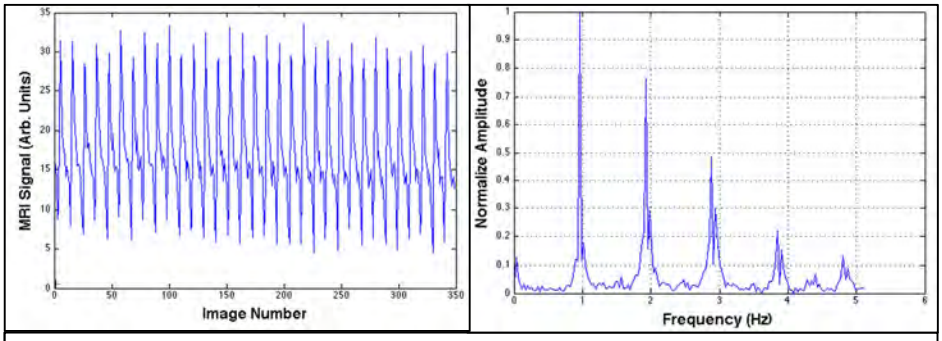

Figure 2. Example of time dependent signal (left) and its spectrum (right) from an ROI in the anterior segmental pulmonary artery. Bandwidth = 5Hz, allowing direct observation of the fundamental and four harmonics. Harmonics >5 are aliased.

Discussion: The vascular contrast for the Mean Q map is primarily due to the difference in spin density between vasculature and surrounding parenchyma. The STD and Fourier Q maps, however, are additionally sensitive to modulations in the signal intensity either at the heart rate (Fourier) or all frequencies (STD). Sources of signal intensity modulation are (i) the influx of fresh blood into the slice each heart beat, (ii) heart beat related in-plane motion of the blood vessels, and (iii) changes in blood volume. Blood vessels with primarily in-plane flow will have a reduced sensitivity to fresh blood in-flow. The fact that the flow near the blue arrows seen in the STD Q map and not in the Fourier map implies there are signal intensity modulations at frequencies other than the heart rate. Figure 2 confirms this.

Conclusion: The Mean and STD, simple statistical quantities, may produce higher quality Q maps from breath-hold lung MRI data than the FD method. One can improve on Q maps by computing the STD as it reflects signal modifications for all harmonic components.

Reference: 1. Bauman et al., MRM 2009 62: 656-664.