HIGH-RESOLUTION PULMONARY PERFUSION IMAGING IN RODENTS USING A SPATIOTEMPORAL MODEL

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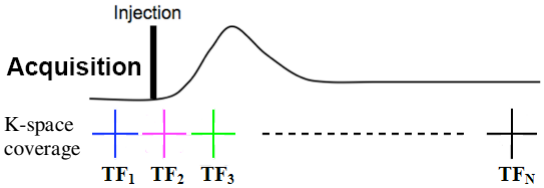
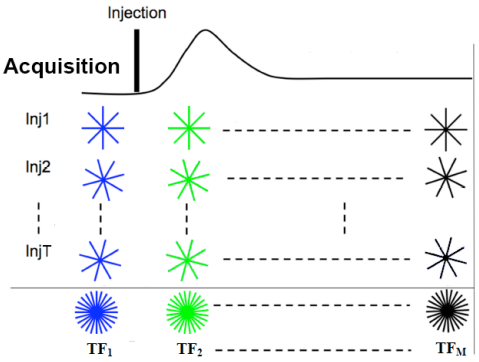
INTRODUCTION: With a large number of genetic rodent models of pulmonary disease available to researchers, there is a need to develop techniques that can characterize pulmonary function quantitatively. Quantitative perfusion imaging in small animals has been recently introduced using multiple contrast bolus injections and image acquisition using Interleaved Radial Imaging and Sliding-window keyhole reconstruction (IRIS) [1]. However, the technique uses a sliding window-keyhole reconstruction technique that has a poor temporal point spread function. We propose a new imaging technique to achieve much higher temporal resolution using spatiotemporal modeling.

THEORY: The proposed technique represents the time-varying image function I(x,t) as an L^{th}-order partially separable function $I(x,t)=\sum c_n(x)\varphi_n(t)$. The temporal variations of I(x,t) are captured by the temporal basis function $\varphi_n(t)$, while the spatial changes are embedded only in the amplitude function $c_n(x)$. Taking the spatial Fourier transform yields $S(k,t)=\sum \alpha_n(k)\varphi_n(t)$. To determine $\{\varphi_n(t)\}$ and $\{\alpha_n(x)\}$ (subsequently $\{c_n(x)\}$), we acquire two separate scans: one with high temporal resolution (16 ms) but very low spatial resolution and the other with high spatial resolution (200 µm) but very low temporal resolution. The first scan is used to model the temporal characteristics of the contrast dynamics. The second scan is used to determine the amplitude parameters of the model. This model enables highly sparse sampling of (k,t) space, which is very desirable for pulmonary perfusion imaging.

METHODS: The acquisitions are performed at suspended breath at end-expiration (10ms) starting with the first detectable ECG R wave to trigger the injector. The injector used for this work delivers 0.05 mmol/kg of the Magnevist ® (Gd-DTPA, Berlex Inc., Montville, NJ) in 50 ms per injection. All images were acquired using dedicated birdcage coils (7 cm diameter, 5.5 cm length) on a 2T Oxford magnet interfaced with a GE EXCITE console running version 12M4 (GE Healthcare, Milwaukee, WI).

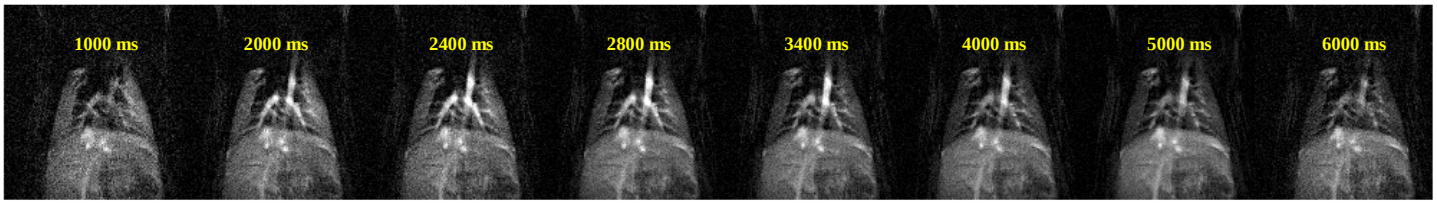


The first scan acquires a sequence of k-space data sets, each with four half radials at the same angles, as shown in the above figure. The radial data are acquired using BW=62.5 kHz, TE/TR = 0.9/4 ms with 256 samples. The cumulative time for each data set (temporal frame) is 16ms. The sampling period for the contrast injection curve is 6400ms, which provides 400 temporal frames. The basis functions $\{\varphi_n(t)\}$ are estimated from these data by performing a principal component analysis (PCA) [2].

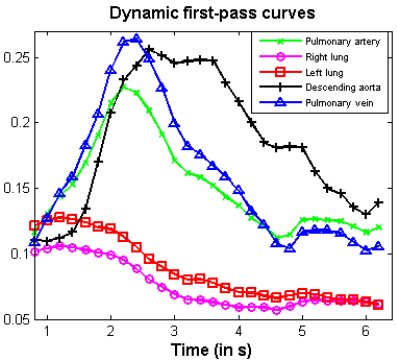


The second acquisition scheme is similar to the first one, except that we cover the k-space more densely with 200 half radial lines (or 100 radial lines) for each temporal frame over a time period of 200TR. We collect 8 temporal frames over a period of 6400ms. To increase angular sampling of k-space, we acquire data over 4 injections. The data from each injection cover different k-space angles, which increases the number of radial lines to 400 for each temporal frame. These data are fitted with the proposed method, which takes into account the fact that each temporal frame is collected over 200TR. After the model fitting, instantaneous (k,t)-space data frames are generated for image reconstruction.

RESULTS:



Time series data in rat lungs shows the bolus tracking capabilities of the image sequence at high spatial (~200 µm) and high temporal resolution.
Time curves showing the dynamic first pass of the contrast agent at different regions of interest are shown in the low left figure:



DISCUSSION: The proposed imaging scheme is flexible in its choice of spatiotemporal resolution and the number of injections. Our experimental results demonstrate that this technique requires data acquisition over 5 injections, leading to a significant reduction in contrast dose as compared to traditional dynamic acquisition which requires 32 injections. It also improves the temporal resolution to 16ms in contrast to 200ms with an IRIS reconstruction.

CONCLUSION: This paper presents a new method for perfusion imaging in rodents based on a spatiotemporal model using multiple injections. Experimental results indicate a ~6-fold improvement in temporal resolution as compared to the existing IRIS method. The proposed technique can have a significant impact on pulmonary perfusion imaging.

REFERENCES:

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