Pulmonary Perfusion Phase Imaging using Self-gated Fourier Decomposition MRI

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Target Audience: Clinicians interested in pulmonary perfusion MRI and MR physicists interested in self-gating and Fourier Decomposition.

Purpose: Providing spatially resolved functional information of the lung without the necessity for contrast media, Fourier Decomposition (FD) MRI (1) recently gained a lot of interest. Both, perfusion and ventilation weighted images are reconstructed performing a simple Fourier analysis of an extended non-triggered time series of previously registered morphologic lung images. In this work, we demonstrate that perfusion-weighted data obtained by SENCEFUL MRI (2), a Fourier Decomposition based technique, carries also information about the phase of the pulmonary perfusion. First patient measurements indicate that this phase may contain valuable diagnostic information.

Methods: Lung perfusion measurements were performed using the SENCEFUL method (2). As outlined in Fig. 1, this advancement of the Fourier Decomposition technique obtains the morphologic image series by cardiac and respiratory self-navigation of data sampled in quasi random fashion (3). Assuming that within that series, all signal changes over time are perfusion related, a perfusion weighted image of the lung can be obtained from absolute value of the first frequency component of the time series' Fourier decomposition (2). At the same time, the relative time shift of these perfusion induced signal changes is encoded in the phase of this first frequency component.

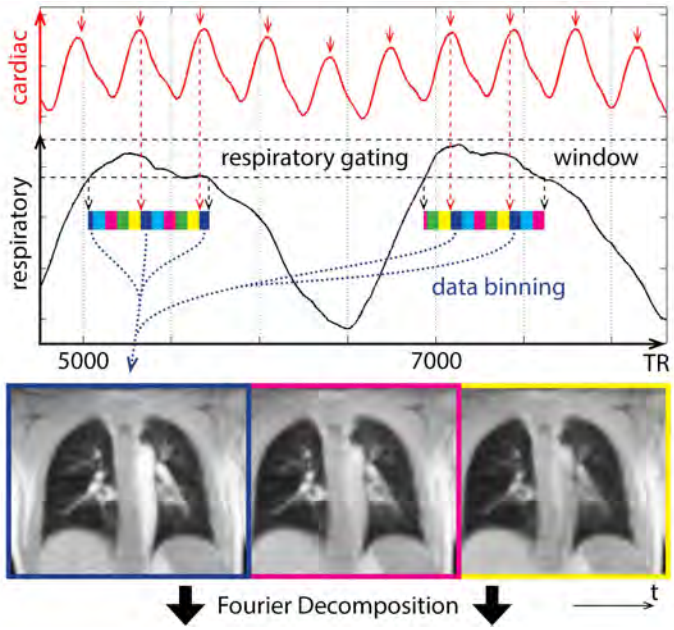

Fig.1: *Schematic overview of the SENCEFUL technique. Using the DC signal from coils close to the diaphragm (black signal curve) and aorta (red signal curve), the quasi randomly sampled data is binned with respect to the respiratory state (chosen gating window) and cardiac phase (time point after maximum in DC signal) at the time point of the data acquisition. An image series of a complete cardiac cycle at a well-defined respiratory state is reconstructed and subsequently Fourier decomposed.*

Pulmonary perfusion amplitude and phase measurements on 3 volunteers and 2 patients were performed on a 1.5 T whole body system (MAGNETOM Aera, Siemens AG, Healthcare Sector, Erlangen, Germany) equipped with a spine and body array coil (34 channels) for signal reception. A 2D FLASH sequence (FOV: 450 x 450 mm^2, Matrix: 128 x 128, Slice thickness: 10 mm, TR: 2.5 ms, TE: 0.69 ms, T_{Acq}: 160 sec, flip angle: 8 deg, asymmetric readout) providing an additional DC signal acquisition each TR for self-navigation (2) was used for imaging. For each slice, from a total of 64,000 quasi randomly sampled readouts, a series of 40 time-frames in end-expiration was reconstructed and Fourier decomposed for the calculation of the perfusion and perfusion phase maps. The coils for self-navigation and data binning were automatically detected.

Results: Representative perfusion weighted and relative perfusion phase maps for a healthy volunteer (left) and a 30 year old patient with cystic fibrosis without acute infectious exacerbation (right) are depicted in Fig. 2. As expected, the perfusion map in the healthy subject (left) reveals a homogeneous perfusion weighting in both lungs. The larger vessels are also clearly visible. The corresponding perfusion phase map (middle left) reveals that the perfusion induced signal changes exhibit similar behaviour over time in all parts of the lung. For the patient, the maps show a significantly higher inhomogeneity, several areas show reduced perfusion (middle right) and a significantly higher phase dispersion (right).

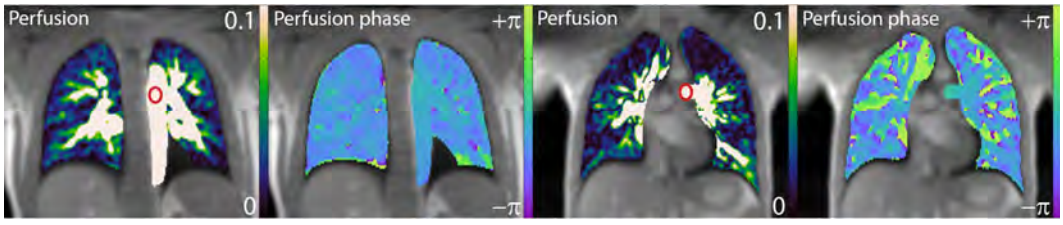

Fig.2: *Perfusion (relative to perfusion in blood-filled voxels) and perfusion phase maps (relative to phase in blood-filled voxels) obtained from a healthy volunteer (left) and a 30 year old patient with Cystic Fibrosis (right). The red circle indicates the blood-filled voxel utilized for normalization).*

Discussion: Without applying contrast agent, pulmonary perfusion phase maps could be successfully obtained using SENCEFUL. Being based on a time series' Fourier decomposition, the maps describe a new contrast in pulmonary MRI. The measurements performed so far indicate that the phase dispersion in patients differs from that in healthy subjects. Hence, the phase information may contain diagnostically valuable information and might be helpful for refining the diagnostic information given by perfusion maps. As in healthy persons, the perfusion induced signal changes can be expected to be in phase with that in the larger blood vessels (e.g. the descending aorta) a significant phase dispersion may refer to a prolongation of the blood flow through the lung. A detailed examination of the diagnostic capabilities of Fourier decomposition based perfusion phase MRI is subject to future work.

References: [1] Baumann, et al. Magn Reson Med 62:656-664 (2009). [2] Fischer, et al. NMR Biomed. 27:907-917 (2014). [3] Weick, et al. Proc Intl Soc Magn Reson Med 19 (2011), #924.