

# Non-Contrast-Enhanced Preoperative Assessment of Lung Perfusion in Patients with Non-Small-Cell Lung Cancer using Fourier Decomposition Magnetic Resonance Imaging

Gregor Sommer<sup>1,2</sup>, Michael Puderbach<sup>3</sup>, Marcel Koenigkam-Santos<sup>3,4</sup>, Christopher Draenkow<sup>5</sup>, Claus-Peter Heussel<sup>3</sup>, Hans-Ulrich Kauczor<sup>6</sup>, Heinz-Peter Schlemmer<sup>2</sup>, and Grzegorz Bauman<sup>7,8</sup>

<sup>1</sup>Radiology and Nuclear Medicine, University of Basel Hospital, Basel, Switzerland, <sup>2</sup>Radiology, German Cancer Research Center (DKFZ), Heidelberg, Germany, <sup>3</sup>Radiology, Thoraxklinik Heidelberg, Heidelberg, Germany, <sup>4</sup>Radiology, University Hospital of the School of Medicine of Ribeirao Preto - University of Sao Paulo, Ribeirao Preto, Brazil, <sup>5</sup>Surgery, Thoraxklinik Heidelberg, Heidelberg, Germany, <sup>6</sup>Diagnostic and Interventional Radiology, University Hospital Heidelberg, Heidelberg, Germany, <sup>7</sup>Medical Physics in Radiology, German Cancer Research Center (DKFZ), Heidelberg, Germany, <sup>8</sup>Medical Physics, University of Wisconsin School of Medicine and Public Health, Madison, WI, United States

## Introduction:

Surgery is the only option for curative treatment of Non-Small-Cell Lung Cancer (NSCLC). As lung function disorders are common comorbidities in patients with NSCLC, knowledge about preexisting lung function defects is important for predicting functional outcome and optimizing surgical procedures. Fourier decomposition MRI (FD MRI) has been introduced recently as a method for regional lung function assessment without contrast agents [1,2]. FD MRI utilizes very short echo-time imaging of the native proton signal with subsequent image registration and spectral analysis to generate perfusion- and ventilation-weighted images. This study is the first to investigate the capability of FD MRI as a tool for preoperative assessment of regional lung perfusion in NSCLC patients. The technique is validated against dynamic contrast-enhanced MRI (DCE MRI) as the standard of reference.

## Methods:

Fifteen patients (5 men, 10 women, mean age: 64y, age range: 49-75y) with NSCLC were prospectively included. Time-resolved image data of the lungs were acquired at 1.5T in coronal and sagittal plane using an optimized free breathing 2D bSSFP sequence (TR=1.9ms; TE=0.8ms; TA<sub>image</sub>=119ms; TA<sub>section</sub>=49.5s; FA=75°; section thickness=15mm; in plane resolution=3.5x3.5mm<sup>2</sup>). Respiratory motion was corrected with a non-rigid image registration algorithm [3]. Fourier decomposition was used to detect and separate periodic changes of lung proton density caused by respiratory and cardiac cycles. Perfusion-weighted images were created by pixel-wise integration of the cardiac spectral line. For DCE MRI, a coronal 3D TWIST sequence (Time-resolved angiography With Interleaved Stochastic Trajectories) was used and subtraction images were calculated. Two readers assessed image quality of FD and DCE perfusion-weighted data and analyzed the data visually for lobar perfusion defects. In a quantitative analysis, left to right lung perfusion ratio and perfusion proportions of pulmonary lobes were calculated. Overall FD MRI perfusion signal per lung volume was compared to quantitative perfusion measurements by velocity-encoded cine imaging.

## Results:

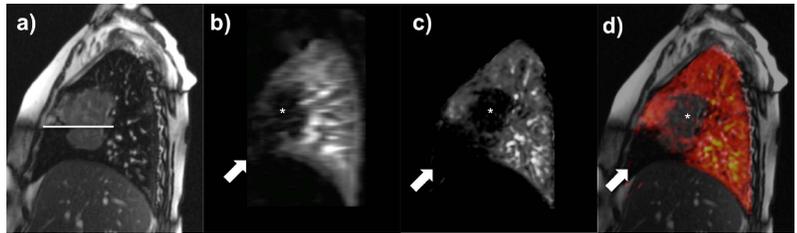
Image quality of FD MRI was rated very good in 7%, good in 83%, and non-diagnostic in 10% of cases and thus was significantly inferior to DCE MRI (90%, 10%, and 0%; P<0.0001). A sample case is given in Figure 1. Visual analysis revealed a sensitivity of FD MRI in detecting lobar perfusion defects of 84% (average from 2 readers) and a specificity of 92%. Accuracy was 91%. Quantitative evaluation of lobar perfusion provided high linear correlation between FD MRI and DCE MRI for both lungs (right: r=0.96; left: r=0.97) and both upper lobes (right: r=0.93; left: r=0.91). Considerably lower linear correlation was found for both lower lobes (right: r=0.57; left: r=0.64) and the middle lobe (r=0.46). Bland-Altman analyses revealed no significant bias for individual lobes (P=0.1-0.7). Limits of agreement (95% CI) between FD MRI and DCE MRI were highest for the right lower lobe (±13.1ml/s) and ranged between ±6.4 and ±8.5ml/s for the remaining areas (Figure 2). Comparison of average perfusion signal per lung volume and average pulmonary arterial blood flow showed high linear correlation (Figure 3).

## Discussion and Conclusion:

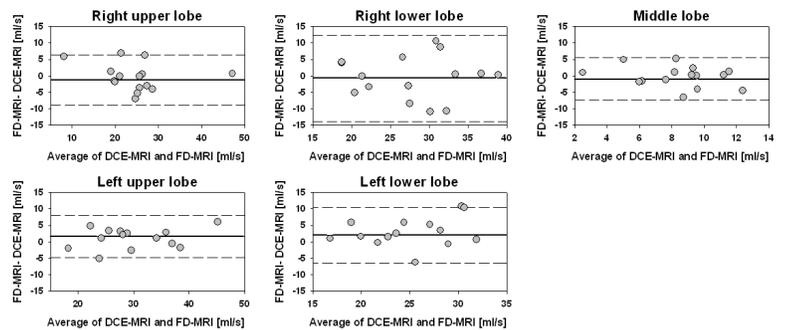
Non-contrast-enhanced preoperative assessment of regional lung perfusion in NSCLC patients with FD MRI is feasible and applicable in clinical routine. FD MRI provides high sensitivity, specificity and accuracy in detecting lobar perfusion defects compared to DCE MRI as standard of reference. The image quality of FD MRI has shown to be less than that of its reference DCE MRI. FD MRI can quantify bilateral and lobar perfusion proportions with sufficient accuracy in both upper lobes and for bilateral comparison, but is in its present form limited by pulsation artifacts in the lower parts of the lungs. Further investigation must address the problem of cardiac pulsation artifacts and validate the technique in larger patient cohorts.

## References:

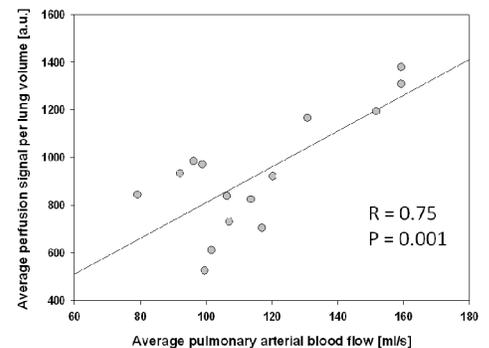
- Bauman G et al. Non-contrast-enhanced perfusion and ventilation assessment of the human lung by means of fourier decomposition in proton MRI. *Magn Reson Med*. 2009;62:656-64.
- Bauman G et al. Pulmonary Functional Imaging: Qualitative Comparison of Fourier Decomposition MR Imaging with SPECT/CT in Porcine Lung. *Radiology*. 2011;260:551-559.
- Chefd'Hotel C et al. A variational approach to multi-modal image matching. In: *Proc. IEEE Workshop on Variational and Level Set Methods in Computer Vision*; 2001:21-28.



**Figure 1:** 74 year-old woman with stage IV (T2 N2 M1b) adenocarcinoma: a) sagittal bSSFP image, b) sagittally reformatted DCE MRI perfusion map, c) sagittal FD MRI perfusion map after manual segmentation, d) fusion image containing original bSSFP image and color-coded FD MRI perfusion map. The bulky tumor mass in the right upper lobe (asterisks) extends across the minor fissure (horizontal line in a) and towards the right hilum thereby causing a perfusion defect in the entire middle lobe (arrows), which is identified well with both DCE MRI and FD MRI.



**Figure 2:** Bland-Altman diagrams comparing absolute values for regional lung perfusion in ml/s measured by FD and DCE MRI. Solid lines: mean deviation. Dashed lines: limits of agreement (95% CI).



**Figure 3:** Scatter plot showing linear correlation between average FD MRI perfusion signal per lung volume and average pulmonary arterial blood flow as measured by velocity-encoded cine MRI.