

Quantification of Pulmonary Perfusion using Fourier Decomposition Method

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Purpose: The Fourier Decomposition (FD) method [1] is established as a non-invasive method for ventilation and perfusion related information in the lung, where the perfusion maps in particular have been shown to be promising for clinical use [2]. However, the perfusion maps are non-quantitative and dimensionless, making follow-ups and direct comparisons between patients difficult. In this work we demonstrate how to obtain physically meaningful and quantifiable perfusion maps from healthy volunteers using the FD method. The results are compared to SEEPAGE perfusion measurements which have shown high consistency with DCE perfusion MRI [3, 4].

Method: The FD method uses Fourier analysis to find and extract the image signal at a temporal frequency corresponding with the heartbeat. The signal at this frequency is then extracted from the original signal, giving us the perfusion maps. Theoretically this signal consists only of the blood flow and can therefore be used to quantify the perfusion. Given a high enough temporal resolution we can observe the in and out flow of blood in the lung and since we know the acquisition time for each image we can calculate the perfusion using the relative amount of blood in a voxel (voxel filling factor) similar to what has been proposed by the SEEPAGE technique [3].

Following [3] and [5] we calculate the perfusion f in the lung using the voxel filling factor and the experiment time T_{ex} with the equation $V_{blood}/V_{voxel} = 2 \cdot T_{ex} \cdot f$. Since the blood volume V is proportional to the amount of magnetisation, which is proportional to the image intensity, we can determine the voxel filling factor by comparing the intensity in a partially blood filled voxel with the intensity in a completely blood filled voxel (ex. in the aorta).

Free breathing dynamic images were acquired from two healthy volunteers using a 2D TrueFISP sequence on a 1.5T scanner (Magnetom Avanto, Siemens Healthcare, Erlangen, Germany) with FOV = 450x450 mm², matrix = 256x256, slice thickness = 15mm, in-plane resolution = 1.8x1.8 mm², TR/TE = 300/0.87 ms, GRAPPA factor = 3, FA = 75°.

The images were registered using the Chef d'Hotel algorithm [6] and processed using the standard FD technique [1]. The perfusion map was divided by the number of heartbeats observed and the average time between heart beats was calculated. The perfusion was then calculated as described above.

SEEPAGE perfusion images were acquired for both volunteers using the standard SEEPAGE sequence [4] and the perfusion calculated in the same manner as for FD.

Results: Each lung was manually segmented and automatically divided into six ROIs excluding large vessels. Bland-Altman analysis of the all the ROIs was performed (Fig 1). Each lung was also divided into two parts (top and bottom) and the mean and standard of the perfusion was calculated (Table 1). Figure 2 show example images and perfusion maps of the two volunteers.

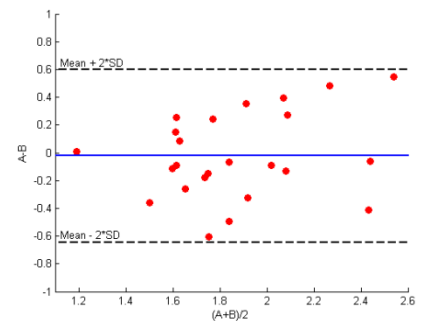


Figure 1: Bland-Altman plot of the two methods.

Discussion: All perfusion values were within the expected values found in literature [3,7] and the Bland-Altman plot shows a mean difference of 0 between the two methods, with all data points well clustered and between the 2 times standard deviation lines, indicating that the two methods are measuring the same variable. Figure 2 and Table 1 show that the perfusion maps and values are in good agreement with each other. Both methods show slightly higher perfusion values for the right lung, as expected from literature [8]. The FD perfusion images are an average over the acquisition time and therefore appear more blurry compared to the SEEPAGE perfusion image.

Conclusion: We demonstrated that quantification of FD perfusion is possible. Perfusion values lie within the expected range and are in good agreement compared to the SEEPAGE method. As a non-invasive quantitative method without breath hold the method is well suited for clinical use, in particular for small children and other non-compliant patients. Further work will compare the results to arterial spin labeling and dynamic contrast enhanced imaging.

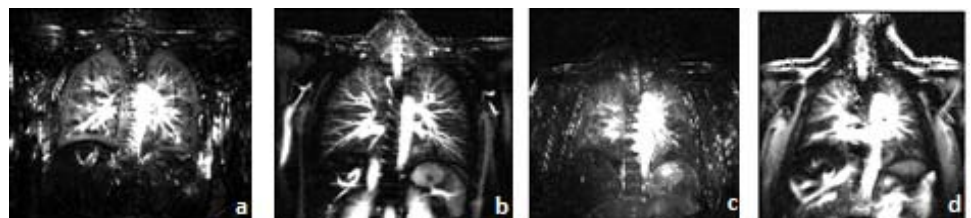


Figure 2: FD (a,c) and SEEPAGE (b,d) perfusion images for both subjects.

Subject 1				Subject 2			
FD		SEEPAGE		FD		SEEPAGE	
R	L	R	L	R	L	R	L
2.04±0.65	1.91±0.55	2.23±0.7	2.06±0.71	1.88±0.59	1.77±0.67	2.00±0.74	1.90±0.79
1.78±0.60	1.46±0.65	1.63±0.8	1.57±0.70	2.20±0.69	1.69±0.67	1.60±0.79	1.50±0.79

Table 1: Perfusion values [ml/min/ml] for top and bottom of the lung using the two methods.

References: [1]: Bauman G, Magn Reson Med 2009, 62(3):656-64; [2]: Baumann G, Proc ISMRM 2012 p 0069; [3]: Fischer A, Journ Magn Reson Im 2008, 27:63-70; [4]: Fischer A, Proc. ISMRM 2012 p 1342; [5]: Buxton RB Magn Reson Med 1998, 40:383-396. [6]: Chefd'hotel C. VLSM'2001, ICCV, 2001; [7]: Schraml C Magn Reson Mat Phys 2011. [8]: Cheng CP Congenit Heart Dis. 2006, 1(5):210-6; [9]: Scheffler, Magn Reson Med 2003, 4:781-783;