Quantification of Pulmonary Perfusion: Comparison of DCE-MRI and SEEPAGE at 3.0 T

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Introduction

The quantification of pulmonary perfusion is of immediate interest to detect abnormalities in the lung at an early stage. Dynamic contrast-enhanced (DCE) MRI is the gold-standard lung perfusion quantification technique. However, DCE-MRI is invasive and accurate quantification is only feasible if the contrast agent (CA) passage is temporally sufficiently sampled. This usually takes several seconds, leading to long breathhold times. Lung patients may not be able to comply with this. Moreover, only a limited amount of CA can be administered, meaning that the repeatability is limited. SEEPAGE is an alternative non-invasive non-CE method to accurately quantify pulmonary perfusion [1,2]. Only a short breathhold of approx. 3 s is necessary, leading to higher patient comfort. Furthermore, SEEPAGE can be repeated arbitrarily often because blood is used as endogenous CA. Even though it was observed that SEEPAGE and DCE-MRI lead to similar values for pulmonary perfusion [2], no study comparing both methods has been performed up to now. In addition, this is the first successful application of SEEPAGE at 3.0 T.

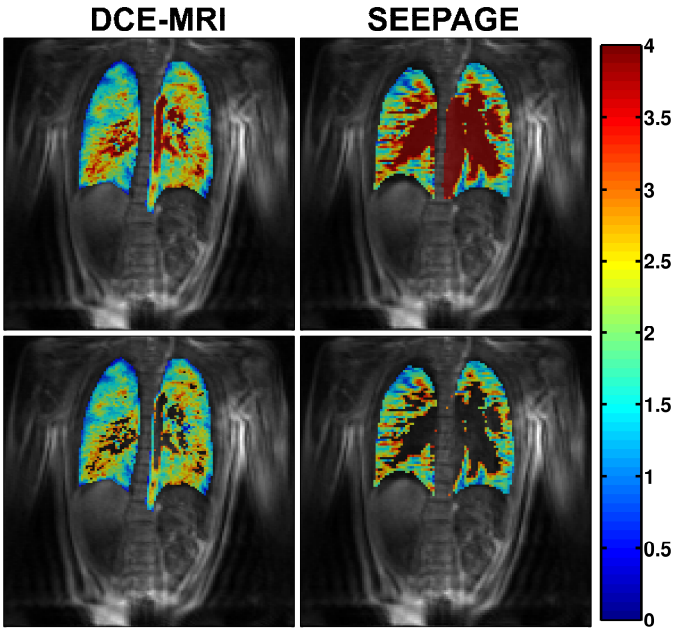

Figure 1: *Quantitative perfusion maps of volunteer 1 before (upper) and after exclusion (lower) of the large pulmonary vessels. Perfusion units: ml/min/ml*

Methods

The goal of this study was to directly compare DCE-MRI and SEEPAGE in terms of quantitative lung perfusion. Four healthy volunteers (3 m/1 f, age 23-24) were included in this preliminary study. All experiments were performed in end expiration. DCE-MRI utilized a prebolus technique which recently demonstrated improved quantitative perfusion maps [3,4]. Imaging parameters: Siemens Trio 3.0 T (Siemens Healthcare, Erlangen, Germany), 32 channel coil (In Vivo, Gainsville/FL, USA), 3D FLASH, α=19°, T_R=1.69ms, T_E=0.64ms (asymmetric echo), af=3 (GRAPPA), FOV 480x435x140mm³, 352x128x28, Gadovist® 1.0 mmol 1ml (prebolus)/4ml (bolus) at 4ml/s (Bayer Healthcare, Leverkusen, Germany). The AIF was determined in the pulmonary artery; the deconvolution was performed using a monoexponential residue function. SEEPAGE [1,2] first spoils the slice magnetization and then repeatedly applies global adiabatic inversion pulses. Inflowing spins from outside the saturated slice lead to a signal enhancement in the imaging slice while the static tissue remains suppressed. A reference SEEPAGE scan in the thoracic aorta was performed to determine the signal level of a completely blood-filled voxel. The signal intensity of the partially filled lung voxels were then compared to these completely filled reference voxels. Since the inflow time (779 ms) was known, quantitative perfusion maps can be generated. The partial Fourier (6/8) HASTE imaging module acquired the SEEPAGE data in the diastolic cycle (ECG triggered) to prevent flow and cardiac motion artifacts. In DCE-MRI and SEEPAGE, a self-developed algorithm iteratively removed the highest perfusion values emerging from the large pulmonary vessels [1,2]. ROIs were drawn in the superior/inferior right and left lung to quantitatively compare DCE-MRI and SEEPAGE. For this purpose, mean values and standard deviations within these ROIs were determined.

	Volunteer 1		Volunteer 2		Volunteer 3		Volunteer 4	
	SEEPAGE	**DCE-MRI**	**SEEPAGE**	**DCE-MRI**	**SEEPAGE**	**DCE-MRI**	**SEEPAGE**	**DCE-MRI**
SRL	2.10 ± 0.63	2.12 ± 0.48	1.65 ± 0.49	1.61 ± 0.39	1.92 ± 0.40	2.15 ± 0.46	1.85 ± 0.56	1.40 ± 0.33
IRL	1.97 ± 0.63	2.29 ± 0.52	2.07 ± 0.76	2.09 ± 0.45	2.06 ± 0.45	2.00 ± 0.43	2.08 ± 0.61	1.73 ± 0.35
SLL	2.03 ± 0.66	1.68 ± 0.36	1.77 ± 0.59	1.52 ± 0.42	2.10 ± 0.41	1.96 ± 0.47	1.61 ± 0.42	1.09 ± 0.25
ILL	2.48 ± 0.79	2.30 ± 0.61	1.93 ± 0.58	1.92 ± 0.46	2.77 ± 0.77	2.12 ± 0.68	2.45 ± 0.80	1.89 ± 0.38

Table 1: *Comparison of quantitative pulmonary perfusion values (after removal of the large pulmonary vessels) of SEEPAGE and DCE-MRI. SRL: Superior right lung; IRL: Inferior right lung; SLL: Superior left lung; ILL: Inferior left lung. Perfusion units: ml/min/ml*

Results

Figure 1 displays the quantified perfusion maps for volunteer 1. It can be seen that both maps are in good agreement which is confirmed by the quantified perfusion rates in Table 1. However, volunteer 4 is an exception where SEEPAGE values are higher than the DCE-MRI values. Furthermore, SEEPAGE results in general in higher standard deviations within the ROIs than DCE-MRI. Nonetheless, all quantified rates agree with recently published pulmonary perfusion rates [3-5].

Discussion and Conclusion

This work reports the first successful application of SEEPAGE at 3.0 T. The presented preliminary study suggests that SEEPAGE and DCE-MRI lead to equivalent quantitative perfusion rates in healthy volunteers. SEEPAGE hereby comes with the advantage of being non-invasive, repeatable, and requiring only short breathholds. The coarser appearance of the pulmonary vasculature in SEEPAGE is a result of 1.) the lower spatial resolution of the SEEPAGE data and 2.) T_2^* blurring due to the partial Fourier HASTE readout. Patients and additional volunteers have to be included in the study to allow a differentiated answer if SEEPAGE and DCE-MRI result in equivalent quantitative pulmonary perfusion values. The initial results of the presented study are nonetheless promising with respect to using SEEPAGE in clinical routine for reliable lung perfusion quantification.

References

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