Quantification of pulmonary perfusion using SEEPAGE

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Introduction

The quantification of pulmonary perfusion is of great importance for detecting lung deficiencies and thereby localizing potential pathologies. Until now, the gold standard in performing perfusion measurements utilized contrast enhanced MRI. This has the disadvantages of injecting contrast-agents and fitting the acquired data to rather complicated functions with free parameters that can be hard to access. In this abstract we present a technique which allows qualitative assessment of perfusion by performing a single measurement and a quantification of parameters by comparing the images to a reliable reference. The experiment is based on the SEEPAGE sequence [1]. The application of this sequence to the human lung, including both the feasibility of obtaining pulmonary perfusion-weighted images with high spatial resolution, and the opportunity to quantify perfusion on a voxel-by-voxel basis, is described.

Methods

All experiments were performed on a Siemens Vision 1.5 T clinical MR scanner. Five healthy volunteers took part in the measurement series (three female, two male, mean age 25.4 ± 2.3 years). The first part of our sequence was a preparation module based on the SEEPAGE sequence (see Figure 1), using a total inflow time of 882 ms. A HASTE imaging module was employed (TE_{Inter} = 4.2 ms/TE_{eff} = 43 ms), the FOV was set to 500 x 500 mm with a matrix size of 128 x 256 half Fourier, yielding a total acquisition time of 1210 ms. To prevent flow artifacts from the aorta [2], ECG triggering was used and imaging was performed solely during diastolic cycle. Our experimental setup for the reference images was a 5mm coronal slice through the thoracic aorta. The perfusion images were obtained by acquiring 20 mm coronal slices. To prevent respiratory artifacts, all experiments were performed within a breathhold at end expiration. Our model to quantify the pulmonary perfusion rate is based on the assumption that during SEEPAGE preparation the "empty" voxel (where "empty" indicates no remaining longitudinal magnetization) fills with blood from outside the selected slice. A comparison of this voxel signal with the reference gives the percentage of blood that has flowed into the voxel. With the well-known inflow time and the voxel size a calculation of the perfusion value for each voxel is possible. In the evaluated lung image, four ROIs (Regions Of Interest) were drawn: whole right lung (RL), superior right lung (SRL), inferior right lung (IRL) and whole left lung (LL) (see Table 1). To better ensure that primarily signal from the lung parenchyma is evaluated, we developed an algorithm which iteratively removed the brightest voxels, i. e. the large pulmonary vessels in the image were eliminated. The mean value was calculated for each ROI before and after excluding bright lung vessels.

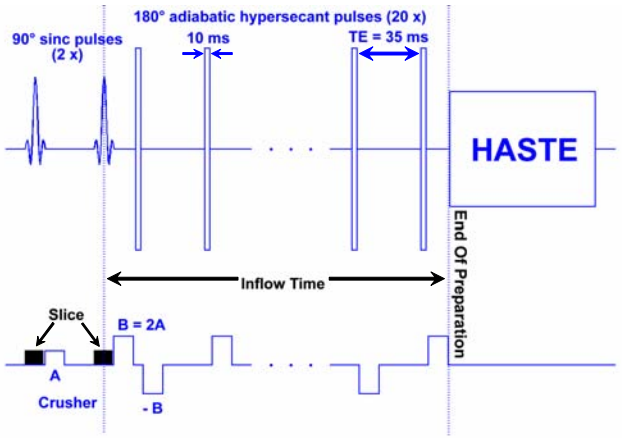

Figure 1: *The SEEPAGE sequence as utilized in our experiments*

	PV	wPV	PV	wPV	PV	wPV	PV	wPV	PV	wPV
RL	2.22 ± 0.36	1.81 ± 0.29	1.85 ± 0.30	1.43 ± 0.23	2.97 ± 0.48	1.99 ± 0.32	3,23 ± 0.52	1.70 ± 0.27	2.18 ± 0.35	1.39 ± 0.22
SRL	1,71 ± 0.27	1.47 ± 0.24	1.34 ± 0.21	1.13 ± 0.18	2.26 ± 0.36	2.00 ± 0.32	2.09 ± 0.33	1.64 ± 0.26	1.68 ± 0.27	1.36 ± 0.22
IRL	2.51 ± 0.40	2.12 ± 0.34	1.99 ± 0.32	1.61 ± 0.26	3.00 ± 0.48	1.81 ± 0.29	3.50 ± 0.56	1.80 ± 0.29	2.42 ± 0.39	1.58 ± 0.25
LL	2.58 ± 0.41	2.21 ± 0.35	1.88 ± 0.30	1.33 ± 0.21	4.46 ± 0.71	2.14 ± 0.34	5.61 ± 0.90	1.80 ± 0.29	4.79 ± 0.77	1.17 ± 0.19

Table 1: *Perfusion values obtained from our volunteers. Nomenclature: RL = Right Lung, LL = Left Lung, SRL = Superior Right Lung, IRL = Inferior Right Lung, PV = with Pulmonary Vessels, wPV = without Pulmonary Vessels; Perfusion units: ml/min/ml*

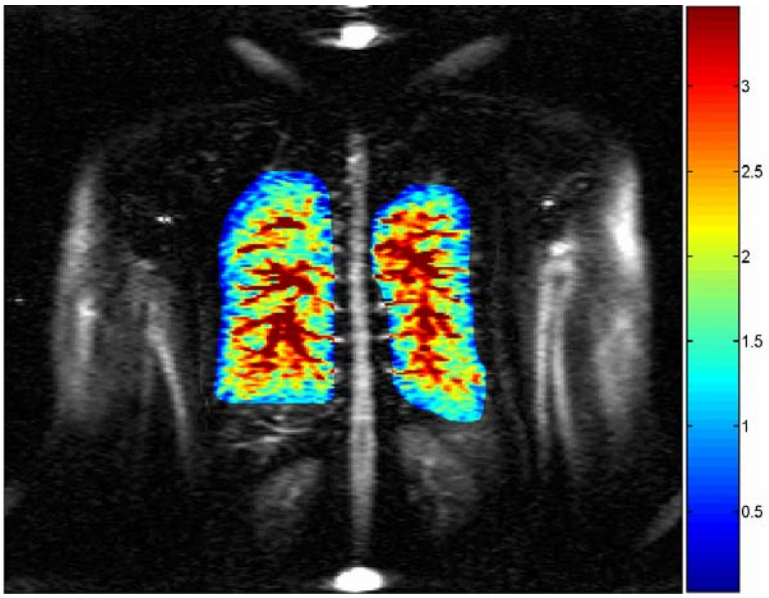

Figure 2: *Typical perfusion image. Note the bright pulmonary vessels, which have not been removed. Perfusion units: ml/min/ml*

Results and Discussion

We were able to show that the initial 90° pulses provide excellent signal suppression below noise level of stationary tissue. In Table 1, the outcome of the experiments performed with the five volunteers is shown. We estimated the maximal error, which is mainly based on variations in our reference experiments, to be 16 %. The perfusion values for all volunteers were similar after the larger pulmonary vessels were excluded from the ROI. In general, blood circulation in the superior lobe of the right lung is lower than in the inferior lobe (note Figure 2). However, due to the fact that our algorithm could not exclude all voxels which clearly belonged to a lung blood vessel, we can assume that our current values overestimate the real perfusion rates. Nevertheless, our quantified rates are reasonable from a physiological point of view. Further improvement in data analysis and error minimization is possible, and an enhancement in SNR is desirable. The sequence is in principle capable of multislice imaging, and this will be the goal of continuing research. Although the sequence has yet to be tested with patients, this method shows promise for future clinical application.

References

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