Validation of Quantitative Contrast-enhanced Pulmonary Perfusion MRI using $H_2{}^{15}O$-PET

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Introduction

Current research shows a variety of different methods for absolute quantification of lung perfusion with MR-technology with the goal to improve the accuracy and reliability of the calculated hemodynamic parameters, i.e. pulmonary blood flow and blood volume. General feasibility has been shown [1] and qualitative comparison of measurements have been conducted [2][3]. Nonetheless a validation by a clinical gold standard, i.e. positron emission tomography (PET) is still absent.

Aim

The aim of the presented study was to validate absolute quantification of pulmonary perfusion by means of deconvolution analysis of dynamic contrast enhanced MRI data using the singular value decomposition approach. $H_2{}^{15}O$ PET-measurements served as an intraindividual reference.

Material and methods

Comparative measurements of pulmonary perfusion were performed on 10 healthy pigs with MRI and PET. Heart rate and blood oxygenation have been monitored to verify stable physiological condition during the examination

MRI was performed on a 1.5 T whole-body MR system (Magnetom Symphony, Siemens Medical Solutions, Erlangen). An ECG-triggered 2D-Saturation-Recovery-Turbo-FLASH pulse sequence was used with two array coils in parallel acquisition mode (GRAPPA; acceleration factor 2). Parameters were chosen for sufficient SNR and temporal/spatial resolution: FA=18°, TI=74ms, scan time per image=120ms, Matrix=128. Hemodynamic parameters were calculated utilizing SVD and indicator dilution theory with a one compartment model after administration of a contrast agent dose (Magnevist, Schering, Berlin) less than 0,025 mmol/(kg BW) (injection rate: 3 mL/s) as described in [4]. Due to expiratory measurements, the specified fraction of tissue, which is defined by the lung density in MR, was estimated to be 0.4.

For positron emission tomography, a scanner with iterative image reconstruction (ECAT EXACT HR+, Siemens Medical Solutions, Erlangen) was employed. 2-3 ml ^{15}O labeled water of an initial activity between 180 and 310 MBq was administered. Hence, PET blood flow values could be calculated – using a model for freely diffusible tracers [5] - from the exchange constant under the assumption of a single tissue compartment and a single plasma compartment.

Results were normalized to blood flow per 100ml ventilated lung tissue. Data was averaged over all images slices of one measurement before comparison.

Results

Comparison shows a general agreement of average blood flows derived from MR and PET measurements (Fig 1), yet the quality of the compliance varies. While there is a very good correspondence observed in some datasets (pigs 2, 4, 5, 8, 9), others demonstrate larger discrepancy (pigs 1, 3, 6).

Discussion

This study demonstrates that - on an intraindividual basis - absolute quantification of pulmonary perfusion by MRI agrees nicely with results obtained from PET.

One important aspect for comparability is the exact value of the tissue fraction in one volume unit. While differing tracer partition coefficients are taken into account by the model used for PET measurements (cf. [5]), the single compartment MR model lacks that feature. Furthermore, indicator dilution theory postulates a transit of the initial amount of contrast agent through every volume associated to a calculated flow [6]. Hence, an additional factor has to be applied to the MR data, which takes into account the aforementioned fraction of tissue. Since in this study that fraction could not be measured directly, it was estimated and chosen constant for all pigs. In order to have reliable results for different breathhold positions and to taking into account different densities of regions within the lung, a method for measuring the density during the perfusion image acquisition would be desirable

Moreover, in the interpretation of the data it must be considered that PET measurements were performed over a period of approx. two minutes, i.e. the PET measurement is influenced by temporal averaging of potential hemodynamic variations like varying blood flows.

A further source for the observed differences between MRI and PET may be the different spatial coverage of both methods. While PET datasets are composed of 63 layers of 2,5mm thickness, MR could only accomplish 4 layers of 8mm thickness. Differences in the mean blood flow values could result from physiological differences due to the different size of observed pulmonary regions. Further measurements with more specimens and hence better statistics, or registration of PET and MRI slices, would be required.

In conclusion, pulmonary perfusion MRI enables reliable quantification of pulmonary blood flow in healthy pigs.

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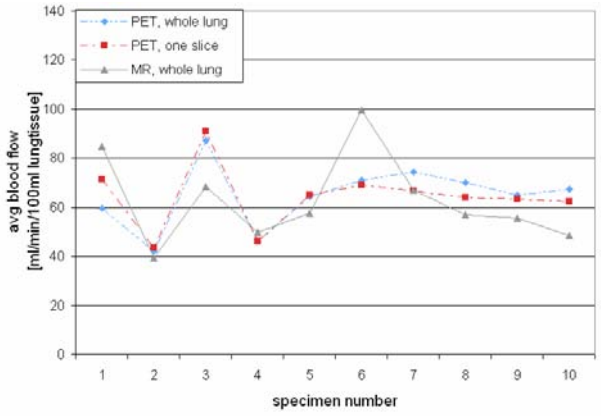

Fig. 1: Intra- and interindividual comparison of averaged blood flows derived from MR and PET measurements.