Validation of Quantification of Regional Pulmonary Blood Flow (PBF) via Contrast Enhanced MRI Using Non-Linear Corrected AIF With $H_2{}^{15}O$ PET

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Introduction

Typical lung diseases in industrial countries like pulmonary embolism, pulmonary hypertension or chronic obstructive pulmonary disease result in a regional decrease of perfusion (1). Hence, it is desirable to quantitatively measure hemodynamic parameters like regional pulmonary blood flow (PBF) for absolute evaluation of regional differences (2-4). PET and MRI measurements could be used as diagnostic tools in the clinical environment. Estimating perfusion with PET by employing ^{15}O labeled water has been standardized and is accepted as standard for perfusion assessment in other organs such as the heart (5,6). While MRI has the advantage of a radiation free examination and better spatial resolution, numerical PBF values still lack validation. The reason for the absence of a validation may be found in the high dependence of the results on various measurement parameters as shown by different groups. One of those parameters is the contrast agent (CA) dose which has to be chosen small enough to ideally get a linear relationship between signal intensity (SI) and CA (7,8) while achieving a sufficient signal to noise ratio (SNR) in the parenchyma.

Aim

The purpose of this study was to expand the MR approach to include the non-linear relation between CA concentration and SI, and to intraindividually compare hemodynamic parameters obtained with both MRI methods and $H_2{}^{15}O$ PET measurements. Thus, the aim of this study was the assessment of the need and the consequence for non-linearity correction, and to validate quantitative pulmonary perfusion MRI.

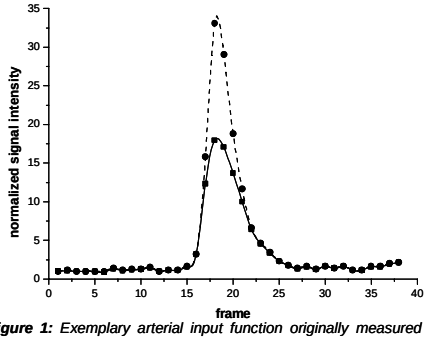

Figure 1: *Exemplary arterial input function originally measured (squares and solid line) and after correction for non-linear relation between signal intensity and contrast agent concentration (circles and dashed line).*

Material and methods

Nine healthy pigs were subsequently examined by MRI (1.5T Magnetom Sonata, Siemens Medical Solutions, Erlangen, Germany) and PET (ECAT EXACT HR+, Siemens/CTI, Knoxville, TN, USA). For estimation of pulmonary perfusion using MRI, the first pass of a contrast agent bolus (Magnevist, Schering, Berlin, Germany) consisting of a dose of less than 0.025 mmol/kg bodyweight was imaged with a 2D Saturation Recovery Turbo-FLASH pulse sequence. The pixelwise signal time curves were deconvolved with the arterial input function (AIF) utilizing singular value decomposition after appropriate signal-time-curve shifting (9-11). The AIF was obtained from the pulmonary trunc A correction for non-linear relation between SI and CA concentration was applied to the AIF based on the signal equations. Calculation of PBF via PET utilized a model of a freely diffusible tracer (injection of 2-3 mL radiolabeled water) and was conducted with a dedicated software tool (PMODVersion 2.8, PMOD Technologies Ltd., Zurich, Switzerland) (12).

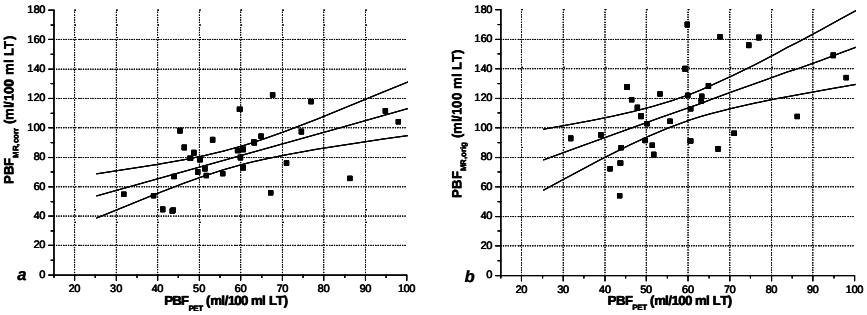

Figure 2: *Graph presenting a ROI based comparison of PBF. Results are shown for dorsal ROIs and* ***a:*** *original AIF and* ***b:*** *corrected AIF. Linear fit and corresponding 95% confidence bands are shown as solid lines.*

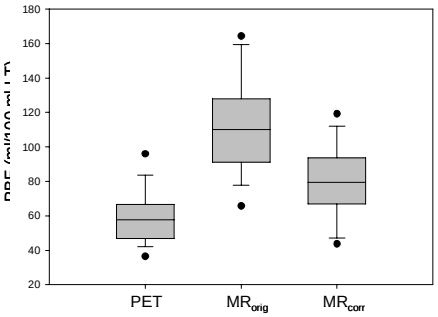

Figure 3: *PBF values of a dorsal ROI as calculated by PET, MR with original AIF and MR with corrected AIF.*

Results

For the chosen sequence parameters a calibration curve has been calculated. In the measurements peak concentrations of AIF (cf. Fig. 1) exceeded the linear range in all cases and all input functions were corrected accordingly. In all cases, the changes in PBF that occurred due to the correction was greater than it would be expected by chance ($P \leq 0.001$ for ROI analysis). Figure 2 shows results of the dorsal ROI-based comparison of all subjects. Correlation of PBF_{PET} and PBF_{MR} was highly significant for both MR methods ($P < 0.001$). Linear fits yielded $PBF_{MR,orig}=1.01(\pm0.27)*PBF_{PET}+52.85(\pm16.62)$ and $PBF_{MR,corr}=0.79(\pm0.20)*PBF_{PET}+33.59(\pm12.13)$. When correcting the AIF, agreement between PET and MR improved and the range of calculated flow values tended to decrease (Figure 3).

Discussion

Deviations from an ideal agreement of PBF_{PET} and PBF_{MR} can be explained by limits in comparability of the two modalities. Main reasons are measurement time and respiratory state during imaging: while MRI was conducted in expiratory breathhold within 40 cardiac cycles, PET mesurement consisted of a total scan time of three minutes during continuous ventilation. Hence the PET measurement is influenced by temporal averaging of potential hemodynamic variations. Reduced comparabilty must also be taken into account when choosing the ROIs within an imaged slice. Although vessels were excluded from the MRI analysis, this may have been incomplete. Moreover, due to the different contrast mechanisms and different spatial resolution of the two modalities, registration of images was not trivial (cf. figure 4). Since the correction factor for the lung density according to the indicator dilution theory (13) could not be measured directly, a constant value was assumed. Estimation of error of the AIF correction yielded a deviation of less than 5% in SI if native T1 is in a range of 1200 to 1600 ms.

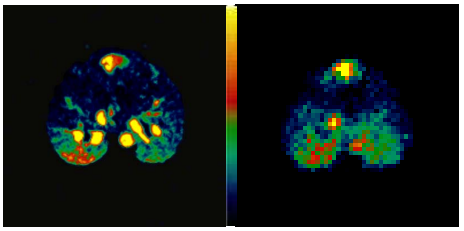

Figure 4: *Color-coded parameter maps showing blood flows derived from exemplary slice with MR (left) and PET (right).*

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References

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