Quantitative contrast-enhanced perfusion measurements of the human lung

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Introduction: The homogen perfusion of the human lung plays, together with the ventilation, a decisive role for the efficient oxygenation of the blood. A multitude of lung diseases produces a defective perfusion. Hatabu et al. [1] used dynamic contrast-enhanced MRI for quantitativ perfusion measurements. For acurate determination of the AIF a dual bolus approach has been introduced [2] and applied to quantitative heart perfusion [3]. Recently, the dual bolus was tested on the human lung [4]. In the present work, we measured first-pass contrast-enhanced pulmonary perfusion with a 1ml bolus and used the prebolus approach to quantify lung perfusion with a 3ml bolus. Additionally, the lung volume and the heart-time-volume were measured to calculate a value for the global lung perfusion (GLP) as an independent relation.

Methodes: All measurements were performed on a 1.5 Tesla scanner (Magnetom Symphony, Siemens Medical Solutions, Erlangen, Germany). The contrast agent Gd-DTPA (Magnevist, Schering, Berlin, Germany) was injected into an antecubital vein using a power injector (Medrad, Volkach, Germany) at a flow of 4ml/s, followed by a flush of 20ml saline. Perfusion images were acquired with saturation recovery TrueFISP (TE/ TR/ TI/ α = 1.1ms/ 2.6ms/ 156ms/ 50°, slice thickness 8mm, FOV = 380 mm^2 , matrix: 128 x 128, supine position). With every injection, a series of 180 consecutive coronary images was acquired with a temporal resolution of 300ms. 6 healthy volunteers (3 male, 3 female, age 25 ± 2) were examined by injection of 1ml and 3ml bolus. All measurements were done in breath-holds in expiration and inspiration, respectively. For mathematical calculations, IDL was used. A ROI was drawn inside the left pulmonary artery to evaluate the 1ml AIF. The AIF for the 3ml bolus was constructed from the 1ml AIF [3]. Signal-time courses of the lung parenchyma were taken from ROIs over the right and left lung, excluding greater vessel. Baseline-corrections were preformed on all signal-time courses. Perfusion values were calculated by deconvolution of the lung signal-time courses with the AIF and an exponential function as residuum. Perfusion maps were generated by fitting the whole lung pixel by pixel.
The lung-volume was determined using a triggered 3D HASTE sequence (TE = 42ms, slice thickness 10mm, FOV = 240 x 320mm^2, matrix: 111 x 256) covering the whole lung in 3 - 4 consecutive measurements in expiration and inspiration breath-holds. The heart-time volume was measured with a cine TrueFISP sequence (TE/ TR/ α = 2.1/ 47.3/ 50°) in expiratory breath-hold. The lung volume and the heart-time volume were evaluated using ARGUS software (Siemens Medical Solutions, Erlangen, Germany).

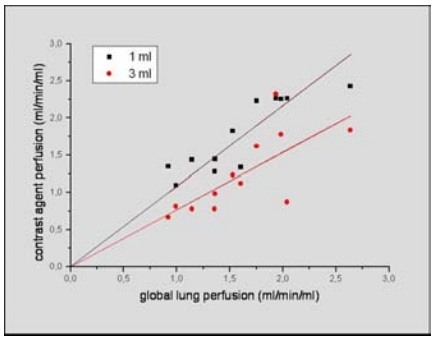

Fig.1: Correlation between the 1ml and 3ml series and the global lung perfusion

Results: The mean perfusion value for the 1ml series was 240 ± 46 ml/min/100ml in expiratory- and 133 ± 46 ml/min/100ml in inspiratory breath-hold. For the 3ml series with the reconstructed AIF, the mean values were 153 ± 46 ml/min/100ml (expiration) and 83 ± 28 ml/min/100ml (inspiration). The measurements of the global lung perfusion (GLP) produced values in the same range, 198 ± 37 ml/min/100ml in expiration and 123 ± 26 ml/min/100ml in inspiration. The correlation coefficient between the 1ml series and the GLP values was R = 0.83 and R = 0.75 for GLP and the 3ml series (Fig.1). The local pulmonary perfusion was displayed with perfusion maps (Fig.2).

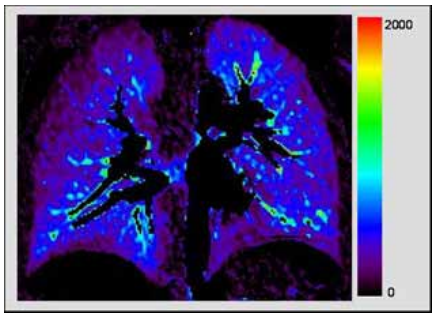

Fig.2: Perfusion map (ml/min/100ml) of a healthy volunteer for a 1ml contrast agent dose.

Discussion: We measured contrast enhanced quantitative lung perfusion with a SR-TrueFISP sequence. All calculated perfusion values yield good agreement with the literature. The application of higher contrast agent doses leads to underestimation of the AIF. With the constructed AIF from the 1ml series, measurements with 3ml doses achieve appropriate results with a higher signal from lung parenchyma. Differences between inspiratory and expiratory breath-hold were detected, with distinctly higher values for expiration. The correlation between the perfusion values and the global lung perfusion (GLP) was good for both contrast-agent concentrations. The next step will be examinations of lung patients to quantify perfusion defects on diseased lungs.

[1] Hatabu et al. MRM 42:1033 (1999)
[2] Christian et al. Radiology 232:677 (2004)
[3] Koestler et al. MRM 52:296 (2004)
[4] Risse et al. Proc. Eur.Soc.Mag.Res.Med.Biol. (2005)