Comparison of contrast-enhanced magnetic resonance perfusion imaging and magnetic resonance Fourier decomposition with single-photon emission computed tomography as clinical reference standard for lung perfusion in patients with suspected chronic thromboembolic pulmonary hypertension

Marcel Gutberlet[1], Christian Schönfeld[1], Jan Hinrichs[1], Julius Renne[1], Georg Berding[2], Marius Hoeper[3], Tobias Welte[3], Frank Bengel[2], Frank Wacker[1], and Jens Vogel-Claussen[1]

[1]Institute of Radiology, Medical School Hannover, Hannover, Lower Saxony, Germany, [2]Clinic for Nuclear Medicine, Medical School Hannover, Hannover, Lower Saxony, Germany, [3]Clinic of Pneumology, Medical School Hannover, Hannover, Lower Saxony, Germany

Purpose: The differentiation of chronic thromboembolic pulmonary hypertension (CTEPH) from other causes of PH has high relevance for the treatment of the disease [1]. Standard clinical methods for the diagnosis of CTEPH are computed tomography pulmonary angiography (CTPA) and single-photon emission computed tomography (SPECT) ventilation-perfusion (V/Q) scanning. In contrast to CTPA and SPECT V/Q scanning, dynamic contrast-enhanced (DCE) magnetic resonance (MR) perfusion imaging and perfusion-weighted (pw) MR Fourier decomposition (FD) allow the determination of lung perfusion without using ionizing radiation. Therefore, purpose of this work was to compare DCE MR perfusion imaging and pw MR FD [2] to SPECT V/Q scanning as clinical reference method.

Methods: Both SPECT V/Q and MR imaging were applied to13 patients with suspected CTEPH. Local ethics committee approval was obtained for the study and all patients gave written informed consent. SPECT perfusion scanning was performed after injection of ^{99m}Tc macro aggregated albumin i.v. (matrix: 128x128, FOV: 60cm, 120-130 slices, slice thickness: 4.8mm) and evaluated by an experienced nuclear medicine specialist blinded to the MR imaging results. MR imaging was applied on a 1.5 T scanner with an 8 channel torso coil. DCE MR perfusion imaging was acquired with a 3D Fast Low Angle Shot (FLASH) sequence (T_E: 0.7ms, T_R: 2.1ms, FA: 25°, T_{acq}: 1.15s, matrix: 113x192, GRAPPA factor 2, FOV: 50cm, slice thickness 6mm, 30 slices) in breath hold in inspiration over 40s after injection of 0.04mmol/kg Gd-DOTA. Lung perfusion was evaluated from the time frame of the dynamic series with maximum signal in the lung parenchyma. Pw MR FD maps were calculated from a time series of 200 images with a temporal resolution of 300ms acquired with 2D FLASH (T_E: 0.7ms, T_R: 1.6ms, FA: 8°, T_{acq}: 150 ms, matrix: 96x128, FOV: 50cm, slice thickness 15mm, 6 slices with 7.5 mm gap) applying a non-rigid registration and a Fourier analysis in the time domain. The MR data were evaluated by an experienced radiologist who was blinded to the SPECT results. For comparison, the lung perfusion was scored for each lung segment with a) segmental, b) subsegmental perfusion defect or c) without perfusion defect. Statistical analysis was performed considering a) segmental and subsegmental perfusion defects or b) only segmental defects using SPECT perfusion imaging as clinical standard.

Results: Figure 1 shows an example of coronal perfusion maps of the three evaluated methods from a patient with CTEPH. In all patients CTEPH was diagnosed by the three methods. The results from the statistical analysis are shown in Table 1 for scoring segmental and subsegmental perfusion defects and in Table 2 for scoring only segmental defects. The averaged distance of time of the SPECT V/Q and MR imaging was 2.1±1.8 days. The kappa-coefficients (κ, with standard error σ_κ) indicate a good agreement of DCE compared to SPECT (κ: 0.51/ 0.54) and a moderate agreement of FD compared to SPECT (κ: 0.23/0.34) and DCE (κ: 0.38/0.36). Comparing DCE vs SPECT the sensitivity (sen) and positive predictive value (ppv) are higher for scoring segmental and subsegmental perfusion defects (83% vs 73% and 80% vs. 63%) while the specifity (spe) and negative predictive value (npv) are higher when scoring only segmental defects (67% vs. 89% and 72% vs. 90%). The intra-observer agreement considering and neglecting subsegmental perfusion defects was good for DCE (κ/σ_κ: 0.54/0.06, 0.66/0.05) and moderate for FD (κ/σ_κ: 0.41/0.06, 0.33/0.06).
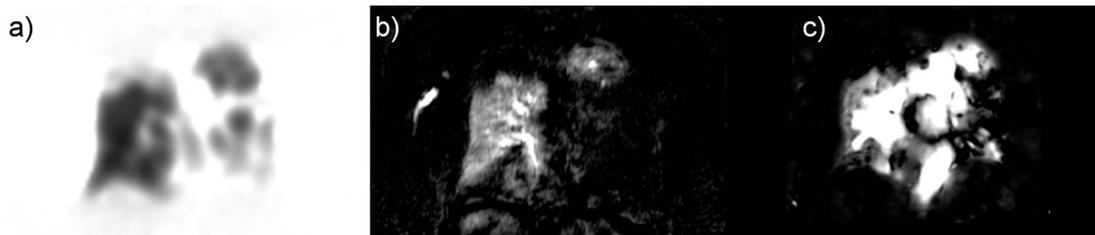

Figure 1: Perfusion map of the identical patient resulting from a) SPECT perfusion scan, b) DCE MR perfusion imaging and c) pw MR FD imaging.

	DCE vs SPECT	FD vs SPECT	FD vs DCE
Sen	83%	78%	83%
Spe	67%	43%	53%
Ppv	80%	68%	75%
Npv	72%	56%	65%
κ/σ_κ	0.51/0.06	0.23/0.07	0.38/0.07

Table 1: Statistics scoring segmental and subsegmental perfusion defects as positive segments.

	DCE vs SPECT	FD vs SPECT	FD vs DCE
Sen	73%	77%	75%
Spe	89%	65%	66%
ppv	63%	44%	50%
Npv	90%	89%	86%
κ/σ_κ	0.54 / 0.06	0.34 / 0.06	0.36 / 0.06

Table 2: Statistics scoring only segmental perfusion defects as positive segments.

Discussion: DCE MR perfusion imaging and pw MR FD allow the diagnosis of CTEPH. The cause for the moderate agreement of the MR methods compared to SPECT has to be further analyzed. Our analysis may be affected by localization errors of the segments (i.e. low spatial resolution, different phases of respiration, artifacts near the beating heart) making a classification of subsegmental defects difficult (moderate intra-observer agreement). In contrast to SPECT and DCE MR perfusion imaging, in MR FD imaging the slices were acquired with 0.75cm gaps and 1.5cm thick slices which may additionally reduce its agreement to the other methods.

References: [1]: Wilkens H, Int J Cardiol. 2011;154 Suppl 1: 54-60   [2]: Bauman G. et al; MRM 2009; 62: 656-664