Dynamic Pulmonary Perfusion and Flow Quantification at 3.0 T vs 1.5 T: Qualitative and Quantitative Analysis

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Background: MRI is being increasingly applied to the study of pulmonary vascular anatomy, perfusion and blood flow. Results at 1.5T have, in general, been positive, and the promise is that performance and image quality can be further enhanced at 3.0T. However, there are substantial technical challenges to thoracic imaging at 3.0T, and to our knowledge, there are no studies comparing pulmonary perfusion and flow imaging at 3.0T and 1.5T.

Purpose: To compare quantitative indices of pulmonary perfusion and pulmonary artery flow at 3.0 T vs 1.5 T

Materials and Methods: 9 adult healthy consecutive volunteers (5 M, 4 F, 28-51 years old) were scanned at 3.0T and 1.5T using a time resolved, 3D echo-shared sequence (1) with near-identical parameters (TR/TE= 2.2/1.0 ms; FA=20º; FOV=400 mm; slice thickness= 9mm; 16 partitions; matrix=240x320; voxel size=1.6x 1.3x 9 mm^3; BW= 1300Hz/pixel; GRAPPAx2). 3.0T imaging was performed on an 8 channel system (Magnetom Trio Siemens) with a body array coil, and 1.5T imaging was performed on a 32 channel system (Magnetom Avanto Siemens) using a 12 elements body array coil. Following injection of 6 ml gadodiamide (Omniscan, Amersham Health Inc.) at 4 ml/s, 3D imaging was performed and reconstructed every 1.6 seconds during a 22 second breath-hold. Magnitude subtraction, in the image domain, of the first (unenhanced) data set from all subsequent data sets was performed online, as was on-axis MIP reconstruction.

For qualitative assessment parenchymal enhancement (PE) phases were selected from the subtracted data sets, and reviewed throughout the volume for the visibility of parenchymal enhancement, lung fissures, and delineation from adjacent chest wall and pulmonary vessels. PE was scored as: poor 1; marginal 2; good 3; excellent 4). SNR evaluation with ROIs on the separate lung fields (excluding major vessels) was performed on the raw perfusion phase. For time-curve analysis, dedicated software was used (MERZ, Siemens Medical Solutions). The algorithm uses a gamma variate fit on a pixel by pixel basis and calculates mean transit time (MTT), time to peak (TTP), maximal signal intensity (MSI), and maximal upslope of the curve (MUS). Using a breath-hold, flow quantifications sequence, MR velocity maps of the main pulmonary artery were obtained in identical planes on both scanners. Through-plane flow encoding with a VENC of 150 cm/sec was used. Images were retrospectively gated using a pulse oximeter. Quantitative analysis was performed using Argus flow analysis software (Siemens Medical Solutions). Quantitative analysis of these flow curves allowed the calculation of net flow volumes, peak flow velocity, and time to peak flow (= acceleration time). Paired t-test was used for statistical analysis.

Results: Technically satisfactory results were obtained in all cases. The mean PE score was significantly higher at 1.5T than at 3.0T ($P < 0.001$), as was the measured SNR during the parenchymal phase ($p < 0.02$). However higher SNR values were identified in anatomic vascular structures at 3T ($p < 0.02$). No significant difference in perfusion parameters ($p > 0.05$) or pulmonary artery flow quantification data were found between 1.5T and 3.0 T ($p > 0.05$).

Figure-1. Dynamic images at 1.5 T, each obtained 1.6 seconds apart show sequential filling of pulmonary and systemic circulation.

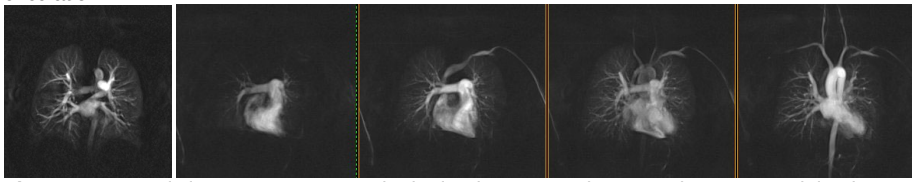

Figure-2. Dynamic images at 3.0 T, each obtained 1.6 seconds apart, show sequential enhancement of the pulmonary and systemic circulation.

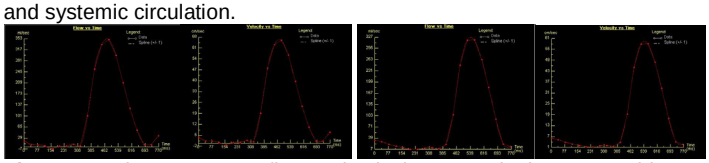

Figure-3. Pulmonary artery flow and velocity curves in the same subject at both 1.5 T (Rt) and 3.0 T (Lt).

Conclusion: These results indicate that, whereas pulmonary arteries and veins may be better visualized at 3.0T, the parenchymal phase of pulmonary enhancement (often related to microvascular perfusion) is better seen at 1.5T. The findings likely reflect the increased magnetic susceptibility effects at 3.0T, most marked in small airways and alveoli, which result in signal loss (2). The higher SNR values of the pulmonary vasculature at 3T is consistent with theoretic predictions (3), although the magnitude of the difference is intermediate. This likely reflects mitigating factors at 3.0T, such as dielectric resonance effects and RF eddy currents, as well as the more optimal RF receiver chain currently implemented at 1.5T. As expected, main pulmonary artery flow quantification was similar at both field strengths.

References:

1. Finn JP et al. Radiology, 2002
2. Uematsu H et al. MRM, 2001.
3. Campeau N et al. MRM, 2001.