Measurement and Visualization of 4D Flow Characteristics in the Portal Venous System with 3T MRI compared to Doppler US

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Introduction: Chronic liver disease can cause severe complications such as liver cirrhosis. It is often associated with pathological vascular hemodynamics in the portal venous system. Recent studies have shown that flow sensitive 4D MRI which permits the measurement of time-resolved three-directional blood flow inside a 3D volume can be a useful tool for the assessment of vascular hemodynamics. The purpose of this study was to evaluate a new imaging protocol depicting anatomical abdominal structures and simultaneously visualizing and quantifying 4D vascular hemodynamics in the portal venous system using flow-sensitive 4D MRI at 3T.

Methods: All measurements in the ongoing study were performed using a 3T MR system (Trio, Siemens, Germany) and a 12-element body coil. The study population consisted of 33 patients with chronic liver disease (mean age: 54.5±13.3), 28 young volunteers (mean age:27.4±2.9) and 22 age matched volunteers: (mean age:57.8±5.6), in total 83 participants. After positioning the liver in the isocenter of the magnet, single shot fast spin echo sequences with half Fourier phase encoding (HASTE) were used to measure morphological scout images in coronal, sagittal and axial orientations. (TR = 750ms, TE = 60ms, α= 160°). Next, flow-sensitive 4D MRI (time-resolved rf- spoiled 3D gradient echo sequence with three-directional velocity encoding) was applied using an axial oblique 3D volume which was positioned along the portal vein (see fig 1). Image parameters were as follows: venc = 50cm/s, spatial res. = 1.6 x 2.1 x2.4 mm³, α= 7°, TE = 3.0ms, TR = 44.8ms, 36 slices per slab, slice thickness = 2.4mm. ECG synchronization and respiration control (navigator at the spleen-lung interface) was applied, requiring particular attention for the accuracy of the two trigger-options. Data acquisition was executed during end-expiration and data acceptance rate was typically greater than 60%. Blood flow in the portal venous system was evaluated using 4D flow visualization (EnSight, CEI, USA) and flow quantification (Matlab) in manually placed planes at defined anatomical landmarks. Results were compared to the reference standard Doppler Ultrasound.

Results: The acquisition of flow-sensitive 4D datasets of the portal venous system was successfully performed in 30 patients (tot. acq. time = 48min ± 11.9min; 4Dflow: 13.8min 7.5min) in 26 young volunteers (tot. acq. mean time = 54.9 min ± 14.9min, 4Dflow: 21.2min ± 8min), and 19 older volunteers (tot. acq. mean time = 48.4min ± 9.8min, 4Dflow: 19.1min ± 7.3min). The average duration of the total examination was 50.5min ± 12.8min while the flowsensitive 4D MRI scan took 17.7min ± 8.2min. 4D flow visualization in the complete portal venous system as shown in figure 2 was successfully performed in 75 of total 83 measurements (90.3%).

The reasons for the failed examinations were diverse. In 3 cases the patient/volunteer compliance was limited because of claustrophobia, in one case the measurement was aborted by the patient, in 2 cases the 4D flow datasets were overwritten and 2 patients suffered from high grade ascites which made image evaluation impossible. Velocity measurements in MRI correlate well with results from Doppler US (table).The comparison of 2D and 4D flow measurements in MRI show no significant different values for peak velocity, flow volume and vessel area. Following parameters were analysed: Peak velocity., flow volume and vessel area

Conclusion: The results of our study demonstrated a positive performance of our MR protocol in 90% of all examined patients and good correlation with the reference standard Doppler ultrasound. In previous studies the feasibility of visualisation and quantification of 4D flow characteristics was already shown [1]. With a further optimized flow-sensitive 4D MRI sequence, particularly with respect to reduced measurement time, MRI may have the potential to provide reliable information about morphology and hemodynamics of portal venous flow.

References: [1], Stankovic et al., ISMRM 09, p.3855; Deibert et al., Pharmacol Ther. 2006;23:121-8; Markl et al., JMRI 2007; 25:824-31