Quantitative MRI at 3.0 T using SENSE: measurement of T_1 and tracer kinetics in the kidney

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Introduction.

Body MRI at 3.0 T is developing rapidly stimulated by the introduction of parallel imaging technology. However, the difficulties of performing quantitative imaging studies at high field have limited the use of functional techniques. The purpose of this study was to develop and evaluate a quantitative dynamic contrast-enhanced (DCE) imaging protocol incorporating SENSE to reduce SAR and bookend T_1 measurements to calculate contrast agent concentration in the presence of B_1 inhomogeneity. The protocol was evaluated in a study of renal perfusion and function at 3.0 T.

Methods.

Data were acquired on a Philips Achieva 3.0 T MR system employing a combination of whole-body quadrature and torso phased-array coils. T_1 measurements were validated using a Eurospin II T05 phantom that was calibrated using a single slice inversion recovery (IR) spin echo sequence (TR 10 s, TI 10 – 5000 ms). Two sequences were tested: a single slice, single shot IR-TSE sequence (6 TIs; 100 – 2000 ms) and a 3D multiple shot IR-turboFLASH (IR-TFE) sequence employing SENSE (intershot delay 4 s; TI 78, 500, 2000, 3850 ms). The IR-TSE sequence was subsequently used in 6 healthy volunteers (24 – 35 years old) to measure T_1 of renal parenchyma and liver. One volunteer returned on 2 further occasions to test the reproducibility of the measurements.

Eight patients (61 – 76 years old) with atherosclerotic renovascular disease were scanned using the 3D IR-TFE sequence to measure T_1 both before and after a low dose DCE acquisition (0.025 mmol/kg Gd-DTPA-BMA). These bookend T_1 measurements were used to correct the DCE data for B_1 imperfections [1]. The dynamic acquisition employed a 3D FLASH sequence (17° flip, TR/TE 5.05/0.87 ms, SENSE factor 2) with volumes acquired every 2.1 s for 4.5 minutes. The T_1 measurement and DCE images were acquired in an oblique coronal plane encompassing both kidneys and the descending aorta. At the end of each patient study high resolution contrast-enhanced MRA was performed (0.175 mmol/kg Gd-DTPA-BMA) using BolusTrak. The study was approved by the Local Research Ethics Committee.

Results.

The IR-TSE and IR-TFE acquisitions provided estimates of T_1 in the phantom with RMS errors of 7% and 5%, respectively (Fig. 1a). T_1 values measured in the renal parenchyma (1636 ± 214 ms) and liver (987 ± 56 ms) of the normal volunteers were reproducible (CoV in a single volunteer: 3.0% in the kidneys and 6.6% in the liver) and compared well with previous published studies at 3.0 T [2]. Successful DCE studies were performed in all 8 patients providing excellent image quality. Example data from one study are shown in Fig. 1b. The arterial input function was measured in the descending aorta and a renal signal was sampled from the parenchyma of the left kidney. The right renal artery was severely stenosed (Fig. 1c) and the right kidney showed little contrast uptake.

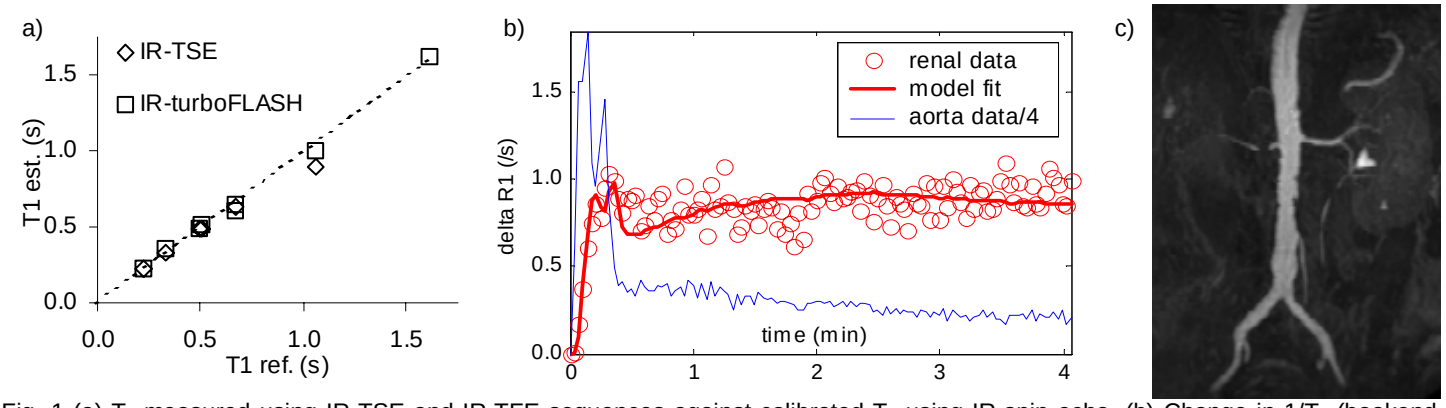

Fig. 1 (a) T_1 measured using IR-TSE and IR-TFE sequences against calibrated T_1 using IR-spin echo. (b) Change in $1/T_1$ (bookend-corrected) against time in the descending aorta (scaled down by a factor of 4) and left renal parenchyma of a patient. Perfusion in the left kidney was estimated at 117 ml/min/100 ml [3] while CE-MRA indicates near complete occlusion of the right renal artery (c).

Discussion.

There is considerable interest in the development of quantitative MR studies at 3.0 T but challenges remain, in particular issues of SAR and B_1 homogeneity. We have limited the SAR of our dynamic acquisitions through the use of SENSE with an increased TR. This has the additional benefit of enhancing baseline renal SNR by over 35%. Furthermore, the introduction of accurate bookend T_1 measurements allows us to correct the influence of B_1 variation on our dynamic data [1]. This reduced the estimate of renal perfusion by 13% in the example data (Fig 1b). In summary we have demonstrated a sensitive and accurate high temporal resolution 3D methodology for the quantitative assessment of contrast agent kinetics at 3.0 T.

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