Error quantification in pharmacokinetic parameters derived from DCE-MRI data using a novel anthropomorphic dynamic prostate phantom

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Aim: Dynamic contrast enhanced (DCE) MRI, in combination with Pharmacokinetic (PK) modelling of the data, has shown considerable promise in the detection of many cancers, including prostate. However, a lack of consistency with published PK parameter values, such as the volume-transfer constant (K^{trans}), coupled with widely varying acquisition protocols and PK modelling approaches, has hindered the clinical implementation of this technique. A method is currently lacking to comprehensively validate the ability of DCE-MRI techniques to accurately measure PK parameters. To address this shortcoming a novel anthropomorphic MRI test device has been developed which is capable of simultaneously producing two MR-measurable contrast time-intensity curves (CTCs), representative of those observed in healthy and tumorous prostate tissue, from which PK parameters can be derived and compared with known 'ground truth' values, allowing for the quantification of any errors in the MRI measurements.

Methods: 'Ground truth' CTCs were measured using a custom-built high spatiotemporal resolution optical imaging system, and ground truth PK parameter values derived from the optical data. DCE-MRI data were acquired using a 3T scanner (Achieva, Philips, Netherlands) and a 16-channel phased array detector coil (3D-SPGR, TR/TE=3.6/1.75ms, $\alpha=10°$, voxel size=1.1x1.1x4mm^3, FOV=224x224x72mm^3, slices=18). The parallel imaging factor and number of signal averages were varied to give temporal resolutions from 2.3s to 20.3s.

Results: K^{trans} values derived from MR-data from the phantom were compared with the ground truth values and were found to differ by -8.1% to -44.6%, with the lowest variance from ground truth values achieved at a temporal resolution of 6.8s.

Conclusion: The phantom provides a model system for the quantitative validation of new and existing prostate DCE-MRI techniques, and could help contribute to the standardisation of clinical prostate DCE-MRI acquisition protocols.