Motion artefact correction in quantitative MRI (qMRI) by linear relaxometry modelling

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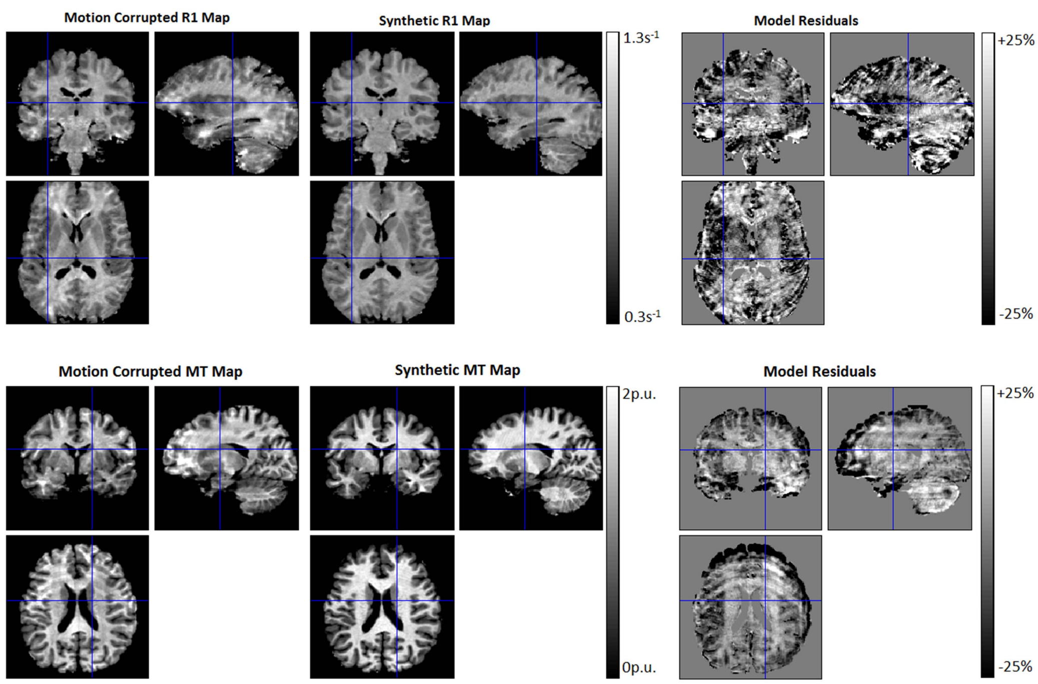
Target Audience: Those interested in quantitative MRI (qMRI), relaxometry and motion artefact correction.

Purpose: The accuracy and utility of quantitative MRI measures are degraded in the presence of subject motion. 3D volumetric acquisitions provide high SNR data useful for achieving high resolution but are particularly sensitive to motion because of the rather long acquisition times. Here we use a multi-parameter mapping (MPM) protocol in conjunction with a linear relaxometry model to generate quantitative maps with increased robustness to subject motion.

Methods: The multi-parameter mapping (MPM) protocol consists of acquiring multi-echo 3D fast low angle shot (FLASH) datasets together with calibration data to correct for B_1 inhomogeneities and constructing quantitative maps of magnetisation transfer (MT), effective transverse relaxation rate (R_2*) and longitudinal relaxation rate (R_1) using bespoke MATLAB tools (The Mathworks, USA) as described in Weiskopf *et al.*[1]. In the absence of any contrast agents, variation in tissue R_1 can be modelled empirically as: $R_1(r) = \beta_0 + \beta_1 MT(r) + \beta_2 R_2^*(r) + \varepsilon(r)$ [2,3]. Here β_0 is the R_1 of free water under physiological conditions; MT and R_2* are surrogate markers for macromolecular and iron concentrations respectively [4,5]; the β parameters are global constants; ε(r) is the voxel-wise residual of the least squares fit between the measured and modelled R_1 values. The residuals capture noise that leads to inconsistencies across the constituent maps, including that caused by motion artefact occurring in a subset of the data. The parameters of the relaxometry model can be estimated by a least-squares fit across all brain voxels (those identified as having a gray or white matter probability >40% and a CSF probability <50% by automated segmentation using SPM8). An artefact-free synthetic map can be regenerated from the model using the β parameters and unaffected maps. This approach was tested on two motion-affected MPM datasets acquired on a 3T whole body system (TIM Trio, Siemens Healthcare) at 1mm isotropic resolution.

Results: In the upper row, the motion artefact was primarily manifest in the R_1 map. The synthetic R_1 map regenerated from the model is largely artefact-free. In the lower row, the motion was primarily manifest in the MT map. The synthetic MT map again appears largely without artefact. In both cases, the motion artefact is captured by the residuals of the model.



Conclusions: Modelling and exploiting the inter-dependency of quantitative multi-parameter maps facilitates the removal of inconsistencies caused by e.g. head motion. Robustness to motion is an important requirement for quantitative imaging, particularly for the study of non-compliant subjects, e.g. patients suffering from involuntary head motion.

Acknowledgement: This work was supported by the Wellcome Trust.

References: 1. Weiskopf, N. *et al.* Front Neurosci, 2013; 2. Callaghan, M.F. *et al.* ISMRM 2013, #3008; 3. Rooney, W.D. *et al.* MRM 2007. 4. Langkammer, C. *et al.* Radiology, 2010; 5. Schmierer, K. *et al.* Ann Neurol, 2004.