3D sequences used for DCE-MRI can exhibit initial instabilities that will affect T1 quantification

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Introduction

Dynamic contrast enhanced (DCE) imaging allows for the characterization of vascular tissue properties, such as local tissue perfusion rate and capillary permeability. To model the pharmacokinetic behaviour of the injected contrast agent, precise and accurate pre-contrast T1 estimates are essential. By evaluating the DCE-MRI protocols using phantom (test object) measurements we have found that changes in measurement sequences and acquisition parameters can have a significant effect on the short-term stability of dynamic data, and thus the T1 estimates and resulting model accuracy. Our findings suggest that it is essential to assess the short-term dynamic behaviour of measurement protocols used for DCE examinations.

Methods and Materials

Eurospin TO5 gels [1] (with T1 values ranging from 200 ms to 1300 ms) were used to assess the short-term dynamic stability of a number of sequences during the creation of a clinical protocol. Before each experiment the gels and loading annulus were equilibrated to scanner room temperature. The ordering of the scans was changed on each occasion to minimise the effects of long-term scanner instability (arising from coil heating or RF instability) on a particular sequence.

Data were acquired on a Siemens Avanto 1.5T. Before the dynamic stability was investigated, the accuracy of T1 measurements was optimised by adjusting the flip angles for a pair of images (proton density and T1 weighted) [2]. The acquisition parameters used for the stability tests were PD_{W1} (3D gradient echo TR/TE/FA 3.8/1.59/3), $T1_{W1}$ (3D gradient echo TR/TE/FA 3.8/1.59/16), PD_{W2} (3D VIBE TR/TE/FA 3.05/0.89/3) and $T1_{W2}$ (3D VIBE TR/TE/FA 3.05/0.89/16). PD weighted images had either 4 or 8 averages, dynamic T1 weighted images were acquired for 1 to 4 minutes. The VIBE sequences were acquired with and without: k-space centric re-ordering, elliptical sampling and under-sampling (phase and slice).

The acquired data were analysed using a software QA tool written in IDL. The software provides an estimate of T1 for each vial at each time point in the dynamic series. The T1 estimate is typically obtained from the central image partition with a circular ROI placed inside each vial and calculated according to Fram [3]. All partitions can be analysed in a similar manner enabling the evaluation of the volume slice profile. The number and position of partitions providing accurate T1 estimates are obtained. Typically 60% of the acquired volume provides accurate estimates of T1.

Results

We have frequently observed an initial short-term (40 seconds to 2 minutes) magnitude drift in T1 weighted gradient echo acquisitions. The drift is substantial; starting at 8-12% above the plateau T1 value, see Figure 1. VIBE acquisitions rarely showed any signal drift, although a small (2%) variation was sometimes observed over the initial 10-20 seconds. Acquisitions acquired without centric re-ordering displayed an additional deviation in the first dynamic sample point. This was often large ± 10% of T1 for high T1 values. The introduction of centric re-ordering eliminated this artefact, as expected. The use of elliptical k-space sampling increased the random dynamic variability of a data series. The standard deviation of T1 measurements (for all T1 values) across a data time series were 7.8 and 11.5 ms, with full and elliptical sampling respectively. A reduction in the dynamic variability of sequences was observed when using phase and slice encode under-sampling; resulting in a standard deviation of only 4.7ms in elliptically sampled data with centric re-ordering (83% and 6/8 phase and slice under-sampling respectively).

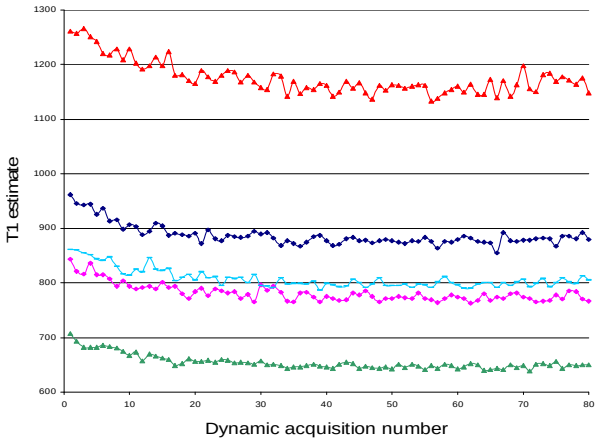

Figure 1. Short-term GRE signal drift for a selection of T1 samples. Each colour represents a different T1 sample (1210, 940, 786, 780, and 625 ms)

Discussion and Conclusions

The signal drift seen in the GRE experiments is significant and would adversely affect any dynamic data acquired in this time period. If this sequence were used in practice it would be necessary to delay the contrast injection until after the initial period of signal drift. The signal drift seen in GRE experiments is unlikely to be a sample heating effect as this would lead to an increase in T1 values not a decrease. Additionally, the ordering of the experiments was changed to minimise longer-term effects such as gradient heating and RF instability. The deviation seen in the first sample point for standard k-space ordering is most likely a magnetisation non-equilibrium effect and needs to be considered when analysing DCE data. We conclude it is essential to perform this level of quality assurance before commencing clinical trials in order to have the required confidence in the DCE-MRI data.

References

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