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Quantitative myocardial inflammation assessed using a novel USPIO-Magnetic Resonance Imaging acquisition and analysis protocol

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Background

Ultrasmall superparamagnetic particles of iron-oxide (SUPIO) particles can be used as a magnetic resonance imaging contrast (MRI) agent. Due to their dextran coating and small diameter (<30 nm), they are phagocytised by inflammatory cells [1].

The aim of this study was to assess whether a novel acquisition/registration USPIO-MRI protocol could be used to assess myocardial cellular inflammation. Myocardial infarction and cardiac surgery was used to model myocardial inflammation [2]. An influx of macrophages can be seen in post-mortem histology, however the dynamics of in vivo patho-physiology is uncertain [3].

Methods

16 patients underwent MRI 2-4 days after ST-elevation myocardial infarction (STEMI) at baseline and 24-hours after intravenous USPIO infusion (4 mg/kg; Ferumoxytol, AMAG; n=10) or no infusion (n=6). Between 5 and 28-days following on-pump coronary artery bypass graft (CABG) surgery, 32 patients underwent the same protocol with all patients receiving USPIO.

3T-MRI (Siemens Medical) was performed to optimise USPIO sensitivity. Baseline and 24-hour multi-echo T2*-weighted sequences were spatially registered to generate an R2* (1/T2*) map to assess USPIO uptake. R2* maps were spatially registered using custom software (Matlab/Analyze) to late gadolinium enhancement (LGE) images to confirm USPIO localisation in the infarct zone. CABG R2* maps were analysed using a standard 17-segment model.

Data comparing CABG to MI cohorts was analysed by one-way and repeated measures ANOVA with Dunn's post-test. Data comparing change in R2* values within cohorts was analysed by Wilcoxon matched pairs test.

Results

Consistent with reticuloendothelial uptake, R2* values increased in the liver & spleen following USPIO administration. In the myocardial infarct, there was a large R2* increase from 41.0±12.0 (baseline) to 155±45.0 s-1 ($p<0.001$) at 24h. A lower magnitude response was seen in the remote myocardium from 39±3.2 to 80±14.9 s-1 ($p<0.002$), consistent with myocardial inflammation that occurs post infarction [4].

In CABG patients the R2* signal increased: 45±7s-1 to 118± 22 s-1 at 24h ($p<0001$). The increase in myocardial R2* values was greater than in the remote myocardium of patients with STEMI, but lower than the infarct zone itself ($p<0.001$ and $p<0.05$ respectively).

Conclusions

USPIO are taken up into inflamed myocardial tissue and can be quantitatively assessed using a multi-parameter MRI acquisition protocol with optimised spatial registration analysis based on a custom mutual information algorithm.

This represents a novel imaging technique of assessing myocardial inflammation, as well as providing a useful research tool in investigating tissue inflammation.

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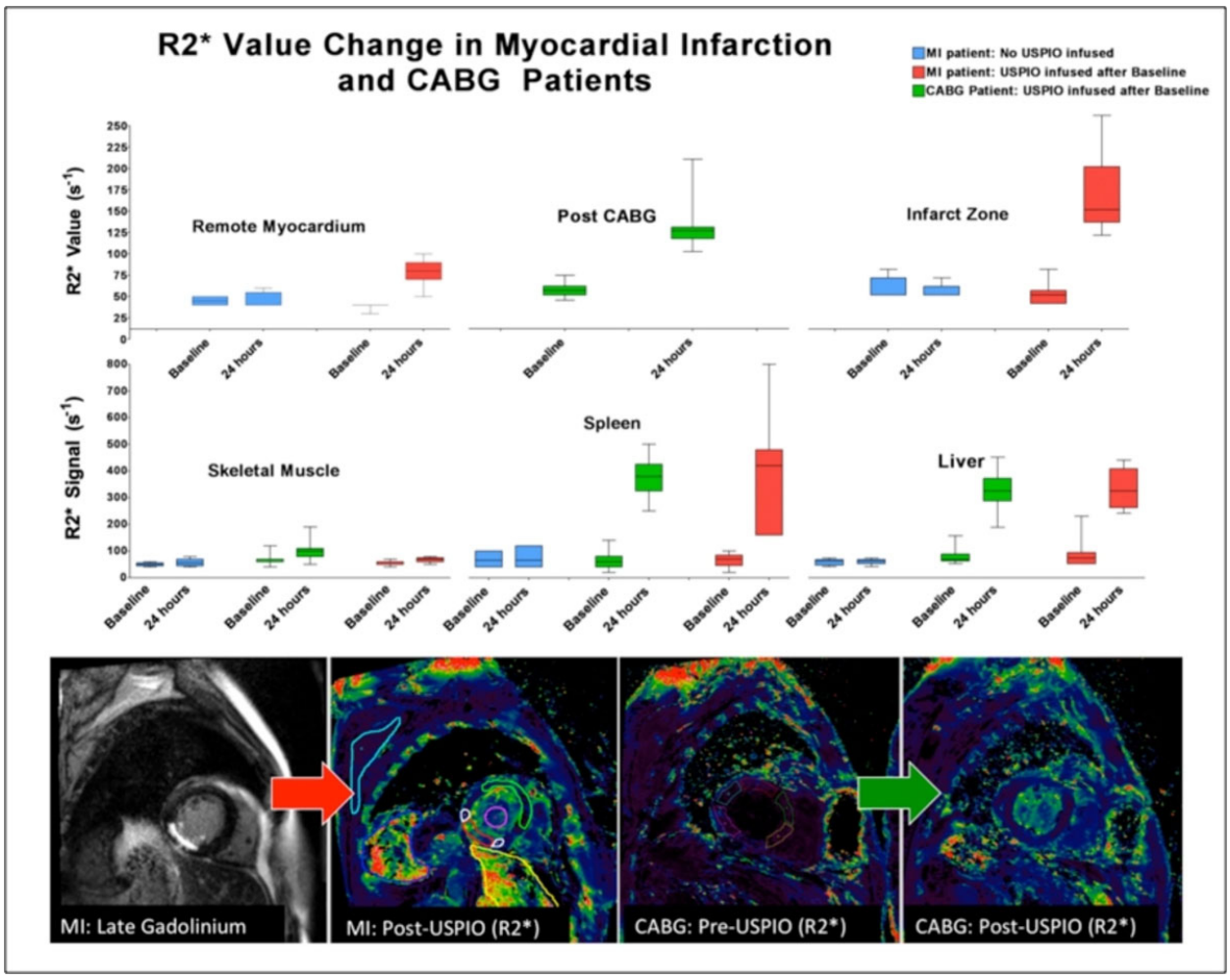

Figure 1 Increase in R2* values in control STEMI patients (no USPIO) (blue, n=6), STEMI patients given USPIO (red, n=10) and CABG patients (green, n=32). Most significant R2* increase (and hence myocardial inflammation) observed in infarct zones, with CABG myocardial R2* increase between infarct and myocardium remote to infarction. The spatially registered regions of interests (ROI) for quantifying R2* value for STEMI and CABG patients are shown in the MRI images at the bottom of the figure.

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