Assessment of myocardial R2 fluctuations over the cardiac cycle under near constant USPIO concentration and relationship with myocardial blood flow

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Introduction

The Ultra Small Particle of Iron Oxide (USPIO) type of intravascular contrast agent has a long residence time in the blood pool [Wang Y.-X. et al. Eur Radiol (2001) 11: 2319-2331]. We explore the potential of such a contrast agent to investigate myocardial perfusion in steady USPIO concentrations without the inherent real-time limitations of first-pass imaging. It has been shown that an increase of blood volume increases the concentration of blood pool contrast agent per unit of volume of tissue, which results in a decrease of the transverse relaxation time ($1/R_2$) [Rosen et al. Magn Reson Med (1990) 14:249-265]. Additionally blood volume fluctuations in a cardiac cycle exist and may be a measure of myocardial blood flow (MBF) [Rodriguez I. Wen H. Talk #641, 12th ISMRM 2004, Kyoto, Japan]. Then in this preliminary study, we investigate myocardial R_2 fluctuation in a cardiac cycle in the presence of USPIO and its correlation with MBF.

Materials and Methods

Four Beagle dogs were used (weight 10.9±1.0kg). Animals were anaesthetized and ventilated at 25 breaths per minute. Acquisitions were done a few minutes after a slow IV injection of the USPIO agent (Combidex, AMI, Cambridge, MA, USA, [Fe]=0-14mg/kg of body weight). In addition some acquisitions were done with a vasodilator (Adenosine infused at 140µg/kg/min) to increase myocardial perfusion.

Scans were performed on a Siemens 1.5T Magnetom Sonata (Siemens Medical Systems, Erlangen, Germany) using a respiration-gated segmented SE-EPI. Seven k-space lines were acquired per shot. The central part of k-space (14%) was always acquired by the central echo to get an R_2 weighted image. A verification of the reliability has been done by acquiring some sets of data with only one k-space line per shot (SE). Six cardiac phases (every 1/6 of cycle) were interleaved in the acquisition. One mid ventricle short axis slice was acquired for two echo times TE1/TE2/TR=23/46/2400ms of each cardiac phase. The images of both echoes were taken at the same moments in the cardiac cycle with the following parameters: FOV=360×158mm^2 (256×114), a slice thickness of 11mm (V_{voxel}=21.4mm^3), B_w=1000Hz/pixel. Dark blood and fat saturation preparations were also used.

Gd-DTPA (0.2mmol/kg) experiments were additionally conducted in order to provide a measurement of the increase of flow with adenosine infusions. We performed first-pass contrast-enhanced imaging and we compare the initial slope of the signal enhancement during contrast wash-in in the two different conditions.

Mean R_2 of the whole myocardium in each cardiac phase was processed in IDL (Research Systems Inc., Boulder, CO, USA). The amplitude of R_2 fluctuation over the cardiac cycle, A_2, was calculated with a sinusoidal fit, and normalized to the iron concentration (measured by the increase of R_2).

Results

Figure 1 is an example of data for a dog for the different studied cases. It can be seen that without USPIO contrast agent, R_2 remained constant over the cardiac cycle. Nevertheless a global R_2 decrease can be seen under adenosine infusion (9%). With USPIO an R_2 decrease is clearly visible from end diastole to end systole with and without adenosine over the 4 dogs. Moreover as it can be seen on figure 2, with adenosine infusion the increase of the normalized R_2 fluctuation is linearly correlated to the increase of Gd-DTPA uptake measured by the initial slope of signal enhancement.

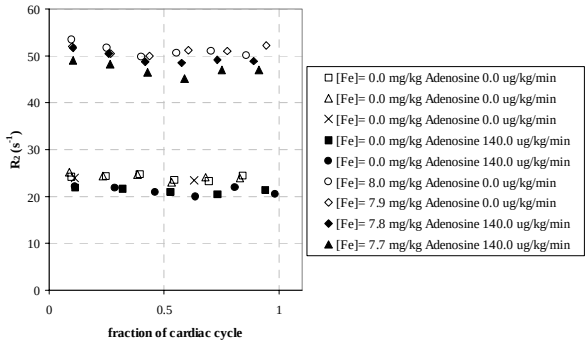

Figure 1: R_2 for Dog #4 as a function of time over a cardiac cycle in different cases. The USPIO concentrations mentioned are estimations. They have been obtained using USPIO half life measurement. × Measurements with SE instead of segmented SE-EPI.

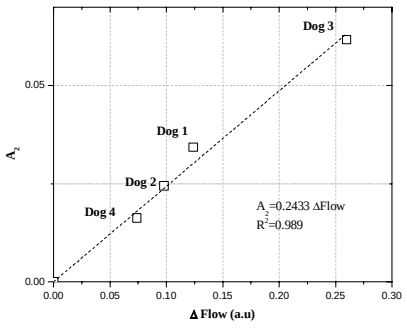

Figure 2: A_2 the amplitude of ΔR_2 normalized to the iron concentration between end diastole and end systole versus the variation of myocardial blood flow before and during adenosine infusion.

Discussion and conclusion

Without USPIO the R_2 variation is difficult to see, but loaded with USPIO the variation over the cycle is enhanced. These preliminary results show first evidences of a quantitative linear relationship (R^2=0.989) between intracycle R_2 fluctuation and MBF in the presence of USPIO. More analysis will be necessary to resolve regional changes of R_2, the correlation with MBF and get an absolute quantification of it.

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