Global measurement of the myocardial perfusion index: application to the assessment of the incomplete Gd-DTPA clearance in rest/stress studies of cardiac perfusion

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Introduction

The feasibility of myocardial perfusion imaging using contrast-enhanced MRI is well established [1]. The introduction of ultra-fast EPI sequences opens the possibility of global assessment of myocardial microcirculation in a clinical setting. In this paper, we present a method for the acquisition and analysis of a global myocardial Gd-DTPA uptake using a model-independent approach for pixel-by-pixel mapping of the perfusion index (PI). Quantitative analysis of PI measurements was performed by applying a histogram based method. This method was applied to measure the influence of residual Gd-DTPA concentration in the blood plasma and myocardium on the MRI measurement of Gd-DTPA kinetics when a second injection of Gd-DTPA is administered in rest/stress perfusion studies.

Methods

Acquisition sequence: A T1 weighted gradient echo sequence with a segmented EPI readout (TFE-EPI) was implemented on a 1.5 Tesla GYROSCAN ACS NT clinical MR imaging system (Philips Medical Systems). T1 contrast is achieved by the use of a saturation pulse applied after the R wave. Six short axis slices were acquired over two heartbeats (for heart rates lower than 150 bps). The total acquisition time for each slice was 90ms (9 RF pulses TR 8.7ms, TE 3.7ms, a=30°, 5 EPI readouts, `halfscan´ factor of 0.71, 128x96 matrix, 6mm slice thickness, 288mm x 193mm Field of View). Gd-DTPA was administered intravenously by a bolus injection (0.05 mmol/kg) followed by a saline flush. The second bolus was administered 30 minutes after the first one and a second perfusion set was acquired using the identical acquisition parameters. No pharmacological stress was applied in the intervening period.

Patient group: Nineteen patients were included in this study (11 male, 8 female with the mean age of 59, ranging from 46 to 69). According to the results of the SPECT cardiac examination they were classified into two groups: normal perfusion (Normal, n=7) and those with fixed perfusion defects (Fixed Defects, n=12).

Quantitative image analysis: Perfusion index (PI) was calculated on a pixel-by-pixel basis as the ratio between the initial rate of enhancement (IRE) in individual pixels and the IRE of the arterial input function (100*IRE yields a percentage SI increase per second). IRE was calculated by applying a moving window algorithm for sequential straight line fitting through four successive time points in each of the normalised SI curves (on average 30000 in each data set). PI values were used for generation of parametric colour maps and computation of PI histograms.

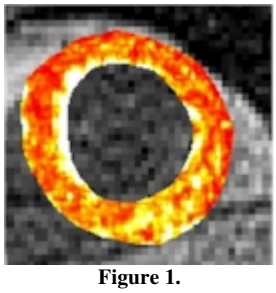

Figure 1.

Parametric map of PI *(Linear colour scale: red = 0.4, yellow = 0.6)*

Each data set was quantified in terms of the median, 25th and 75th percentile. These values were used to compare global PI measurements between acquisitions 1 and 2 as well as the comparison between two patient groups. The differences in PI histograms obtained in repeated measurements were assessed by a paired samples t-test at $\alpha = 0.05$ confidence level. Mann-Whitney test (at $\alpha = 0.05$ confidence level) was used to assess the difference between the measurements of PI in two patient groups.

Results

The measurements of the arterial input function (AIF) in scans 1. and 2. revealed a significant decrease in AIF IRE after the second injection (0.57 ± 0.20 versus 0.27 ± 0.09, mean ± SD, n=17, $p<0.0001$).

Table 2. shows the median PI values in the initial acquisition and two sets of median PI measurements in the second scan. The measurements of 25th and 75th percentiles follow the identical pattern. Mann-Whitney test reveals significant difference between median PI in the subjects with normal cardiac perfusion and those with fixed perfusion defects ($p=0.003$, Figure 2.). When AIF 2. (AIF measured in the second scan) is used for the computation of PI in the second scan, median PI values are significantly higher than those measured in the initial scan and the discrimination between the two patient groups is lost (Mann-Whitney $p=0.083$). In the third row of Table 2. median PI values were computed by using AIF 1. as the denominator to eliminate the influence of alteration in the AIF following the second injection. These values are significantly lower than those measured in the first scan indicating that residual Gd-DTPA affects not only the measurements of the signal behaviour in the blood plasma but also the signal derived from the myocardial tissue. However, the difference between two patient groups is again statistically significant ($p=0.001$).

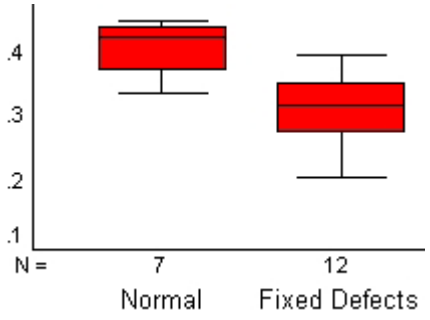

Figure 2.

Distribution of the median of the global PI histograms. Difference between two patient groups was significant ($p=0.003$, Mann-Whitney test at $\alpha = 0.05$).

Discussion

Accurate measurement of myocardial perfusion relies on the linearity of the relationship between the temporal variation of normalised SI in dynamic MRI acquisitions following the intravenous administration of Gd-DTPA. In studies involving repeat injections of Gd-DTPA before the complete contrast clearance is achieved (e.g. rest/stress studies), the residual Gd-DTPA concentration influences the measurements of both blood pool signal and the myocardial microvasculature due to the higher Gd-DTPA concentrations which promote non-linear T2* effects. We have demonstrated that this effect does not affect the capability to discriminate between normal and hypo-perfused myocardium. Absolute measurements of cardiac perfusion, however, need to include accurate measurement of Gd-DTPA concentration and draw an explicit link between signal changes and the underlying temporal variation Gd-DTPA concentration.

References

1. N Wilke et al. Magnetic Resonance Quarterly, 10(4), 249-286, 1994.

Table 1. Median Perfusion Index measurements

	Normal (n=7)	FD (n=12)	p
Scan 1	0.41 ± 0.05	0.32 ± 0.06	0.003
Scan 2 (AIF 2)	0.54 ± 0.09	0.46 ± 0.09	0.083
Scan 2 (AIF 1)	0.28 ± 0.03	0.21 ± 0.04	0.001