Dual T1-Sensitivity Quantitative High-Dose First-Pass Gd-DTPA Myocardial Perfusion

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Aim

To improve the accuracy and reproducibility of Gd-DTPA contrast agent (CA) myocardial perfusion measurement, by optimizing measurement of the arterial input function (AIF) and myocardial signal-time-curve (STC) during the same first-pass.

Introduction

Quantification of perfusion, (e.g. deconvolution or normalized upslope), generally depends on finding the relationship from the AIF to the STC, requiring accurate measurements of both functions during the same first-pass. The AIF may vary greatly and quantification aims to remove sensitivity to this variation. Other variable factors such as surface coil positioning are cancelled out by performing rest and stress first-pass perfusion runs, which requires that the second run is not highly distorted by remaining CA from the first. This abstract evaluates in patients a dual-T1-sensitivity method (1) which during a single high-dose CA injection obtains both a high T1-sensitivity high-resolution myocardial image and a low T1-sensitivity (and low-resolution so therefore very fast) left-ventricular blood image, the latter immediately at each R-wave trigger. In the same first-pass, this method aims to maximize CNR in the STC and eliminate peak distortion from the AIF.

Method

In 15 patients with varying degrees of coronary artery disease, rest and adenosine stress first-pass perfusion short-axis imaging was performed at 0.1mmol/kg (7ml/s, 10ml saline flush). Three mean ROI magnitude ROI measurements for AIFs in the LV were compared: AIF1 from a separate low-dose injection (2) (0.01mmol/kg by dilution otherwise identical to main injection) before each high-dose injection for STC measurement, AIF2 from the new low-resolution low T1-sensitivity 50ms image during the high-dose injection aiming to avoid peak distortion sharing the same first-pass as the high-resolution high T1-sensitivity image used for the STC measurement, from which AIF3 was available *gratis*. The main results were derived by comparing AIF1 and AIF2 both directly and by statistical comparison of myocardial perfusion reserve analyses MPR1 and MPR2 using AIF1 and AIF2 respectively with the STCs. AIF3 was used only for illustration of a well-understood problem. The responses of AIF1 and AIF2 to CA concentration in saline in left-ventricular sized phantoms surrounded by air were plotted, and in addition to some *in-vivo* runs with saturation switched off verified that T2* effects in the larger voxels (but with very short Te) for AIF2 were not significant. For MPR analyses, AIF and TSR values after baseline subtractions were assumed linearly proportional to CA concentration. The constants of proportionality (kCA) differed for AIF1, AIF2 and TSR but were simply assumed not to change between rest and stress, and therefore to cancel out of MPR calculations.

Results and Discussion

The baseline (prior to CA arrival) and peak (of the CA bolus) values of mean LV ROIs for the all the AIFs obtained on all 15 subjects (Figure 1) are shown as % of the blood signal in fully-recovered images without saturation pulses obtained before each injection. Values could exceed 100% because Gd-DTPA recovered saturation caused by the FLASH imaging. The peak distortion of AIF3 made it unusable for quantitative analysis. The baseline and peak values of the highly T1-sensitive AIF1 method were elevated by remaining CA from the earlier rest study, and this sometimes compressed the AIF amplitude (=peak-baseline) at stress for AIF1 in comparison to AIF2 (Figure 2) (but with different kCA sensitivities). Compression at stress due to a lowered constant of proportionality between AIF and CA concentration, caused by high residual CA elevation, could explain the overestimation by MPR1 compared to MPR2 in some of the patients (Figure 3, arrows). No significant difference was found between MPR1 and MPR2 over all fifteen subjects. If two subjects (arrows) with highly overestimated MPR1 were removed, MPR2/MPR1 = 1.11 +/-0.07 became significant ($p<0.05$); the difference was unexplained. Although the serial dual bolus method was the only previously possible approach for quantitative high-dose perfusion, it uses separate albeit close Gd-DTPA first-passes for AIF1 and TSR, whereas the new approach eliminates the separate injection, at the cost of only 50ms per cycle to obtain the low-resolution low T1-sensitivity image for AIF2. AIF2 can use a larger range of the response to Gd without risking compression caused by an elevation of the second run due to residual CA, and therefore offers optimal AIF measurement accuracy. The low-resolution FLASH AIF image method is flexible, for example work in progress prefixes the 50ms AIF2 image to multislice STC imaging by FLASH, SSFP or multishot-EPI perfusion sequences, in which the LV blood signal is unused.

Conclusion

For quantitative high-dose perfusion, the proposed new method offers a potentially superior alternative to the only previously available approach using the serial dual bolus. The small difference in these results requires further work to explain.

References

1. Gatehouse P, Elkington AG, Pennell DJ, Firmin DN. ISMRM10:1605. 2. Christian TF, Aletras AH, Balaban RS, Arai AE. Proc 5th SCMR 2002:93.