Absolute Quantification of Myocardial Blood Flow Using First-Pass Perfusion MRI: Extraction Fraction of Gd-DTPA Varies with Myocardial Blood Flow in Human Myocardium.

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Introduction:

Quantitative analysis of first-pass myocardial perfusion MRI with a Patlak plot analysis can provide absolute quantification of unidirectional transfer constant (K1) of Gd-DTPA in the myocardium, which represents product of myocardial blood flow (MBF) and the extraction fraction (EF) of Gd-DTPA. However, the EF of Gd-DTPA has not been directly measured in human hearts. The purposes of this study were (1) to evaluate the relation between Gd-DTPA concentration and blood signal intensity (SI) on perfusion MRI which is important for accurate correction of blood saturation, and (2) to determine the EF of Gd-DTPA in the resting state and during pharmacological stress in human hearts by using MR flow measurement in the coronary sinus as a reference method.

Methods:

MR images of blood samples from 5 volunteers were acquired by using a saturation recovery True FISP myocardial perfusion MR sequence (Siemens Avanto 1.5T) and a saturation recovery balanced TFE sequence (Philips Achieva 1.5T). The concentration of Gd-DTPA ranged from 0mmol/l to 6mmol/l. The blood SI versus Gd-DTPA concentration curve was determine, which was used for correcting blood saturation in myocardial perfusion MRI studies. Sixteen subjects (9 men, mean age 64+/-12 years) with normal coronary arteries were evaluated with a 1.5T MR system (Achieva 1.5T). First-pass perfusion MR images were obtained with a saturation recovery balanced TFE sequence (TR 3.0ms, TE 1.5ms, TI 150 ms). In order to correct for blood saturation, we initially obtained first-pass MR images by administrating 10%-diluted Gd-DTPA injection (0.005mmol/kg). Then first-pass MR images were acquired at rest and during ATP stress with a dose of 0.05mmol/kg. After correcting saturation of the blood signal, arterial input and myocardial output curves were analyzed with a Patlak plot method to quantify myocardial K1. Phase contrast cine MR images at rest and during stress were acquired to measure coronary sinus flow, and balanced TFE cine MR images were obtained to calculate LV mass. Mean MBF was determined as coronary sinus flow divided by LV mass. The EF of Gd-DTPA was quantified as the mean K1 (by quantitative perfusion MRI) / mean MBF (by coronary sinus flow / LV mass).

Results:

The blood SI versus Gd-DTPA concentration curves were quite similar between 2 different MR imagers when comparable imaging parameters were used. The MR blood SI became nonlinear when blood Gd-DTPA concentration was greater than 0.67mmol/l. In 16 healthy subjects, averaged EF of Gd-DTPA in the resting state was 0.52 +/- 0.16, which showed a good agreement with the rest EF values previously reported in animal studies [1-3]. The EF of Gd-DTPA during stress (0.36 +/- 0.13) was significantly lower than the EF at rest ($p<0.001$). Figure2 demonstrates the relationship between the EF and mean MBF in human myocardium. The fitted curve was expressed as EF=1-exp(-(0.13xMBF+0.59)/MBF). This approximation formula is consistent with the Renkin/Crone equation, EF=1-exp(-PS/MBF), with an indication of slightly increased PS during hyperemia in human heart.

Conclusion:

Blood SI exhibited substantial saturation when the Gd-DTPA concentration exceeded 0.67mmol/l. Nonlinear relationship between blood SI and Gd-DTPA concentration can be corrected with a dual bolus approach using 10%-diluted Gd-DTPA injection. The EF of Gd-DTPA in human myocardium was approximately 0.5 in the resting state, and was significantly reduced during pharmacological stress. The absolute MBF at rest and during stress can be accurately quantified from first-pass contrast enhanced MRI by correcting saturation of the blood signal and MBF-dependent alteration of the EF of Gd-DTPA

References:

1. Svendsen JH., et al. Cardiology 1992; 80:18. 2. Diesbourg LD., et al. MRM 1992; 23: 239. 3. Tong CY., et al. MRM 1993; 30: 337.

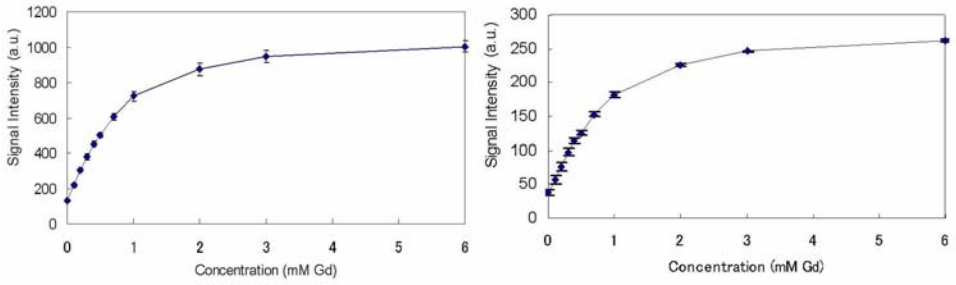

Figure 1. Relation between Gd-DTPA concentration and blood signal intensity (a.u.) on perfusion MR images by two MR imagers (left: Philips Achieva, Right; Siemens Avanto).

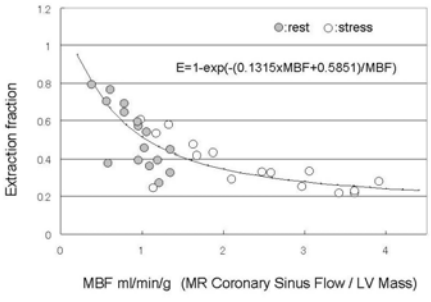

Figure 2. Relation between MBF and extraction fraction of Gd-DTPA.