Validation of Myocardial Blood Flow Quantification with First-Pass MRI in a Pig Model of Acute Ischemia

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The aim of this study was to validate MBF quantification in MRI with Gd-DTPA and the model MMID4 in a pig model using microspheres measurement. Measurements were performed on a 1,5 T scanner during normal blood flow conditions and during occlusion of the LAD. Linear correlation between the MBF values (N=71 segments) obtained by microspheres measurements and by quantification with MRI and MMID4 was r=0.78. Quantification of MBF with MRI has been shown to be a suitable non-invasive tool for evaluation of the significance of a coronary artery stenosis.

Introduction

It has been demonstrated in animal experiments that quantification of MBF can be performed with high accuracy using an intravascular contrast agent (CA) [1]. Furthermore myocardial perfusion index evaluated with contrast enhanced MRI using the extracellular CA Gd-DTPA has been shown to have a high correlation with myocardial blood flow (MBF) evaluated in microspheres measurements [2,3]. But to date quantification of MBF with Gd-DTPA, which is normally used for MRI perfusion measurements in patients with coronary artery disease (CAD), has not been validated. The aim of this study therefore was to validate MBF quantification with MRI using Gd-DTPA and the model MMID4 (Multiple path, Multiple tracer, Indicator dilution, 4 region model) [2] in a pig model by means of microspheres measurements (gold standard for quantification of MBF).

Materials and Methods

Measurements were performed in six anesthetized and ventilated pigs (24-30 kg) during normal blood flow conditions as well as during two different degrees of stenosis in a proximal part of the left anterior descending (LAD). After acute occlusion of the LAD, MBF was allowed to stabilize for at least 30 min. For quantification of MBF, during each perfusion state microspheres were injected into the left atrium. Immediately after completion of the microspheres measurement contrast enhanced MRI perfusion measurement was performed on a Siemens Vision 1.5 T scanner using an ECG-gated Saturation Recovery TurboFLASH sequence (TR/TE/TI/α =2.4ms/1.2ms/10ms/18°). After injection of Gd-DTPA (0.025 mmol/kg), 70 images were acquired in 1-2 short axis slices.

After the MRI study the heart was removed and sectioned into eight rings according to the short axis orientation of the MRI perfusion study. The rings were cut into 8 myocardial segments and absolute quantification of MBF was performed in these segments. For MRI data postprocessing, the myocardium was automatically divided into 8 segments and the signal-time (S(t)) curves were evaluated in these segments and in a region of interest (ROI) in the left ventricular cavity to estimate the arterial input function (AIF). The mean baseline signal intensity S_0 was evaluated in each myocardial segment and in the LV. Normalized signal time curves ($S_N(t)$) in the LV and in the myocardium were calculated by subtracting and subsequently dividing the S(t) curves by S_0. Subsequently $S_N(t)$ was fitted using XSIM software and the model MMID4 [3]. A three-parameter fit was performed with MBF, permeability surface-(PS) product and delay of CA arrival in the myocardium as free parameters. MBF results evaluated by microspheres measurement and by MRI were compared in each segment and for all perfusion states.

Results

The linear correlation between MBF values (N=71 segments) obtained by microspheres measurements and by quantification with MRI was r=0.78 (Fig. 1). During acute ischemia mean MBF obtained by microspheres measurement was (1.33±0.59) ml/min/g in non ischemic sectors and (0.38±0.32) ml/min/g in ischemic sectors. The values obtained by MRI perfusion measurements were (2.19±0.85) ml/min/g in non ischemic and (0.20±0.20) ml/min/g in ischemic regions (Fig 2).

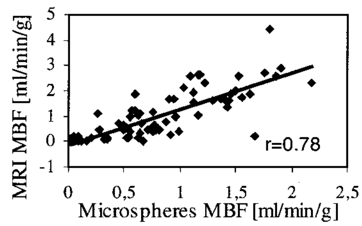

Fig 1: MBF values obtained by MRI perfusion measurements dependent on MBF values determined with microspheres.

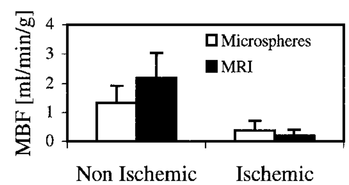

Fig. 2: Mean MBF value in non ischemic and ischemic sectors.

Discussion and Conclusion

The study has shown that absolute quantification of MBF during acute stenosis is feasible with high accuracy using contrast enhanced MRI and Gd-DTPA. Despite the overestimation of MBF in non ischemic regions and the slight underestimation in ischemic regions, MRI data evaluation can differentiate between hypoperfused and normally perfused myocardial regions. The overestimation of MBF in non ischemic regions might be explained by noisy data, as noise causes overestimation of MBF when using the model MMID4 [3]. Underestimation of MBF in ischemic regions, on the other hand, may be a result of dispersion of the AIF in the stenosed arteries [4].

In conclusion quantification of MBF with contrast enhanced MRI measurement has been demonstrated to be a suitable non-invasive tool for evaluation of MBF even in patients with coronary artery stenosis.

References:

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