Myocardial Viability Assessment During Continuous Infusion of Gd(DTPA): Comparing R1-map-based and Signal-Intensity-Based Percent-Infarct-Mapping

P. Surányi[1], P. Kiss[1], B. Ruzsics[1], B. C. Brott[2], T. Simor[1], A. Elgavish[3,4], and G. A. Elgavish[1]

[1]Department of Biochemistry and Molecular Genetics, University of Alabama at Birmingham, Birmingham, AL, United States, [2]Department of Medicine, Division of Cardiovascular Disease, University of Alabama at Birmingham, Birmingham, AL, United States, [3]Department of Genetics, University of Alabama at Birmingham, Birmingham, AL, United States, [4]Elgavish Paramagnetics Inc., Hoover, AL, United States

Introduction

Per-voxel MRI quantification of myocardial infarct distribution based on post contrast relaxation-rate-enhancement(ΔR1), Percent Infarct Mapping (PIM), has recently been developed using an investigational agent, Gd(ABE-DTTA) (Surányi et al, MRM, 2006). In the present work, we achieved delayed-contrast-enhancement (DE) of infarcts using a continuous infusion of Gd(DTPA). We generated PIMs in two different ways: 1) based on R1 (PIM), 2) based on signal intensity (SIPIM). To distinguish absence of delayed enhancement due to viability versus that caused by microvascular obstruction (MO), an automated method was developed utilizing early (3 minutes after Gd(DTPA), T1-weighted perfusion images.

Purpose

To elucidate whether the accuracy of the PIM method is derived from using an intrinsic parameter, R1, or from per-voxel infarct quantification on a continuous scale, and whether it is possible to generate PIMs using simple T1-weighted DE images (SIPIM).

Methods

Four days after reperfused infarction, dogs (n=5) were imaged using a 1.5T GE MRI system. Following Gd(DTPA) bolus (0.2mmol/kg), serial, high-resolution, T1-weighted perfusion images were generated for 12 minutes (Figure 1). Percent signal-intensity-enhancement (SIE%) in all postcontrast images was then calculated pixel-by-pixel, utilizing the precontrast image. Between 2-3 minutes after Gd(DTPA), all regions (viable, patchy-infarct, reperfused infarct) appeared enhanced except those that were non-viable and hypoperfused due to MO (<Remote SI-2SD). These voxels automatically counted as 100% non-viable and a virtual MO-map was generated. Conventional, short axis DE images were acquired covering the left ventricle 15 minutes after Gd(DTPA) using inversion-recovery preparation and nulling the signal from viable myocardium. Next, in the same image orientations, during continuous infusion of 0.0033mmol/kg/min Gd(DTPA), multislice R1-mapping was carried out to generate percent-infarct-maps(PIM) (Figure 1). Inversion-recovery-prepared, segmented, fast-gradient-echo images were generated with six inversion times (TI). In an automated procedure, non-linear curve fitting was applied to calculate voxel-by-voxel R1-maps. A computer algorithm then calculated percent-infarct per-voxel, and generated the PIMs based on relaxation-rate-enhancement(ΔR1), and the SIPIMs based on conventional DE images. Additionally, DE-images were automatically thresholded and enhanced voxels (i.e., SI>Remote SI+2SD) were counted 100% infarcted, and non-enhanced voxels as 100% viable. MO-maps were then virtually merged with thresholded DE-images, and with PIMs (Figure 1). Note that infarct size quantification was automated and the only manual input was tracing of endo-, and epicardial contours and the selection of a remote, viable region. Triphenyltetrazolium-chloride-(TTC)-staining and microscopic histology (hematoxyllin-eosin stained 5μm sections) was used to validate results. Left ventricular infarction fraction (IF) was calculated for PIM, SIPIM, DE and TTC staining to compare the three methods.

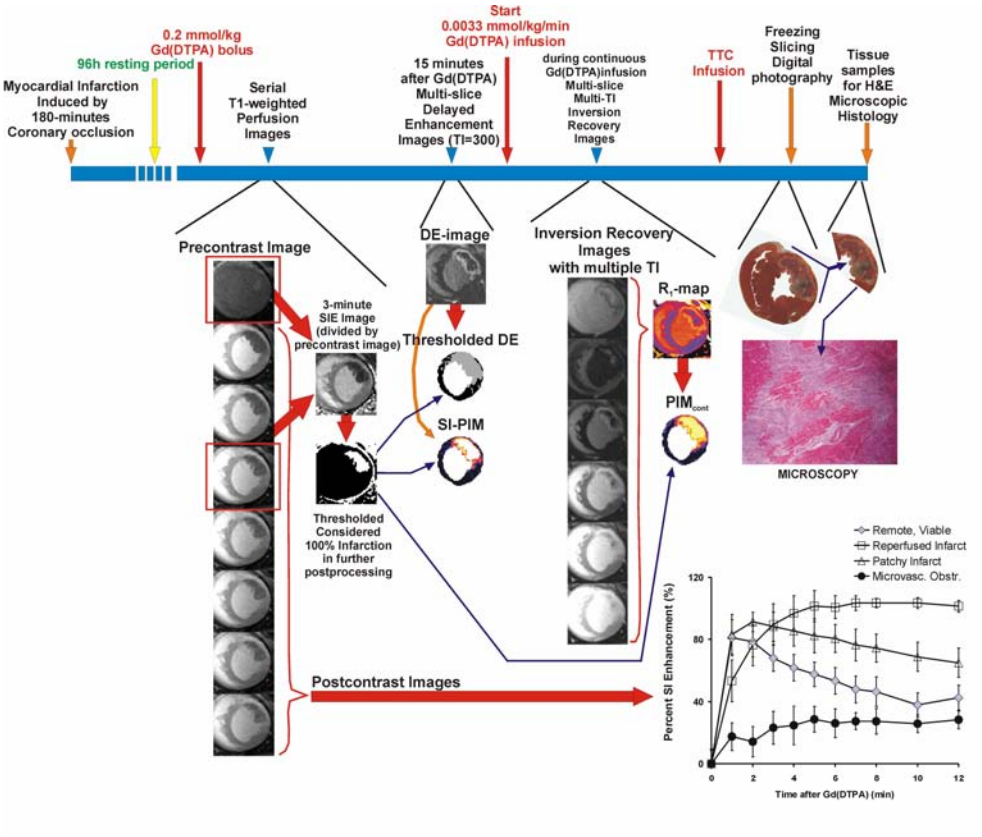

Figure 1. Experimental design, MRI post-processing steps, and postmortem validation..

Results

SIE curves from the four basic tissue types are shown in Figure 1: a) MO (infarcted, yet not enhanced); b) Reperfused infarct (infarcted and maximally enhanced); c) Patchy infarct (partially infarcted thus partially enhanced); d) Remote, viable (100% viable, non-enhanced). IF with PIM_{cont} vs. IF_{TTC} yielded a correlation of R^2=0.99($p<0.05$). Correlations for IF_{SIPIM} and IF_{DE}, both vs. IF_{TTC}, were R^2=0.94 and R^2=0.95, respectively ($p<0.05$ for all). Compared to TTC, median overestimations of IF were 3.1[1.76;4.79], 4.22[1.56;4.62], and 23.2%[22.6,28.8], for PIM, SIPIM and DE, respectively. MO regions corresponded to hemorrhage and nonresorbed coagulation necrosis on microscopy, while there was confluent granulation tissue in well-perfused infarct regions and patchy infarct at the infarct borders.

Conclusions

The greatest advantage of the PIM method is the per-voxel quantification of infarct extent on a continuous scale. Although PIM calculated from R1 is slightly superior to SIPIM, both are more reliable and accurate than traditionally thresholded DE images using a 2SD-threshold. Further, T1-weighted perfusion images early after bolus Gd(DTPA) are useful for objective detection of MO.