# Assessment of Myocardial Reperfusion Injury with Magnetic Resonance Imaging: Segmental Susceptibility-Weighted Phase, Late Gadolinium Enhancement and Rest Perfusion Imaging

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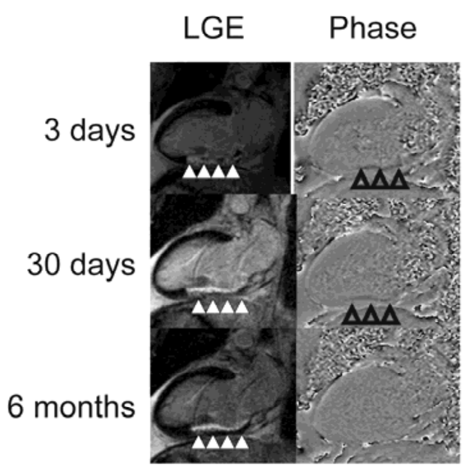
**Introduction:** Emergent reperfusion therapy restores blood flow to ischemic myocardium in acute myocardial infarction (AMI), but can cause additional injury, termed "reperfusion injury" and is associated with adverse outcomes. Intramyocardial hemorrhage is a severe form of reperfusion injury. Detection of intramyocardial hemorrhage has been shown with several MR techniques and is strongly associated with microvascular obstruction (MVO). MVO can be detected using contrast-enhanced imaging such as first-pass rest perfusion and late gadolinium-enhanced (LGE) infarct imaging. Recently, susceptibility-weighted high-pass filtered (HPF) phase imaging was shown to detection myocardial hemorrhage similar to neurovascular applications.

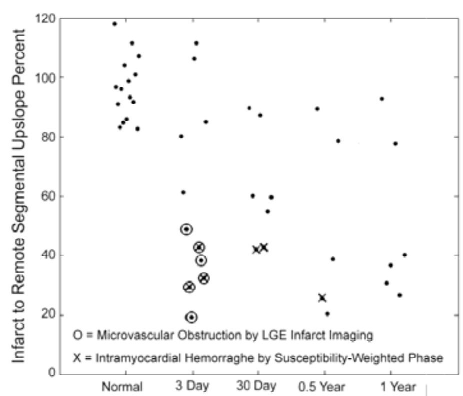
The major aim of this study was to compare HPF-phase imaging in patients with myocardial infarction of varying ages with quantitative resting myocardial perfusion and late gadolinium-enhanced (LGE) infarct imaging.

**Materials and Methods:** Eleven myocardial infarction subjects and 15 age matched control subjects were included for analysis from 44 imaging sessions. The comprehensive MR cardiac study included multiple gradient recalled-echo (12 TEs), first pass resting perfusion and late gadolinium enhanced (LGE) infarct imaging. Region-of-interests were drawn on the short axis images (basal, mid-ventricular and apical) for each subject on each of the 16 AHA segments of the LV and mean phase was computed for each echo delay time. Phase values in MI patients were considered abnormal if outside the normal control range (mean± 2stdev). Semi-quantitative resting perfusion analysis was performed yielding relative mean upslope (RMU) using a computer program written in Matlab. All post contrast data was corrected for heterogeneous brightness in the image by pixelwise division of the mean signal intensity before contrast enhancement. Myocardial upslope was divided by the corresponding LV bloodpool upslope yielding relative mean upslope (RMU). RMU was multiplied by a factor of 10 to yield standard integer values. Also, infarct to remote myocardial upslope ratios were calculated by division of infarct and remote upslopes and multiplied by 100 to yield a percentage value.

**Results:** Myocardial resting perfusion showed changes consistent with myocardial infarction and the presence of MVO and intramyocardial hemorrhage. Segmental resting perfusion in the AMI-Group was significantly reduced when compared to the Control-Group (Relative Mean Upslope (a.u.): Control-Group= 4.96 ± 1.68 vs. AMI-Group= 3.10 ± 1.54, p = 0.008). In the AMI-Group, both myocardium with MVO and hemorrhage had significantly reduced resting perfusion when compared to infarcted myocardium without MVO or hemorrhage (Relative Mean Upslope (a.u.): AMI-Group without MVO= 4.44 ± 1.81 vs. AMI-Group with MVO = 1.98 ± 0.58, p = 0.002; AMI-Group without hemorrhage= 3.86 ± 1.39 vs. AMI-Group with hemorrhage = 1.76 ± 0.52, p = 0.019). Infarct to remote segmental upslope percent showed a similar reduction in resting perfusion with the presence of MVO and myocardial hemorrhage at all stages of myocardial infarction. ANOVA analysis of all subjects showed an incrementally reduced resting perfusion from normal myocardium to infarcted myocardium without hemorrhage to infarcted myocardium with hemorrhage. (Infarct to remote segmental upslope percent: (Infarct to remote segmental upslope percent (%): Control-Group = 96.5 ± 10.6 > MI-Group without hemorrhage = 63.4 ± 26.9 > MI-Group with hemorrhage = 33.5 ± 9.3; p < 0.001). Reduced segmental resting perfusion (<50%) was a sensitive, but not specific indicator of MVO (Sens=100%, Spec=60%) and intramyocardial hemorrhage (Sens=100%, Spec=61%).




Two chamber images from a patient with a transmural inferior wall myocardial infarct resulting from an RCA occlusion. Microvascular obstruction is seen at 3 days in LGE images. Myocardial hemorrhage is visualized in HPF-phase images (TE=15.5 ms).




Infarct to Remote Upslope percent ratio, a semi-quantitative measure of resting myocardial perfusion, shows significantly reduced resting myocardial perfusion in infarcts of all ages compared to the Control-Group. Each patient is represented by a small filled circle. Patients with microvascular obstruction (large unfilled circles) showed significantly reduced resting perfusion compared to those without MVO. Infarcts with intramyocardial hemorrhage (large X), determined by HPF-Phase imaging, also showed significantly reduced perfusion compared to those without.

**Conclusions:** HPF-Phase imagng represents a new quantitative, high quality method for the detection of myocardial hemorrhage and is associated with reduced rest perfusion and microvascular obstruction.