

# Balanced Steady-State Free Precession Magnetic Resonance images Edema in Acute Reperfused Myocardial Infarction – A translational Study in Animals and Humans

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## Introduction

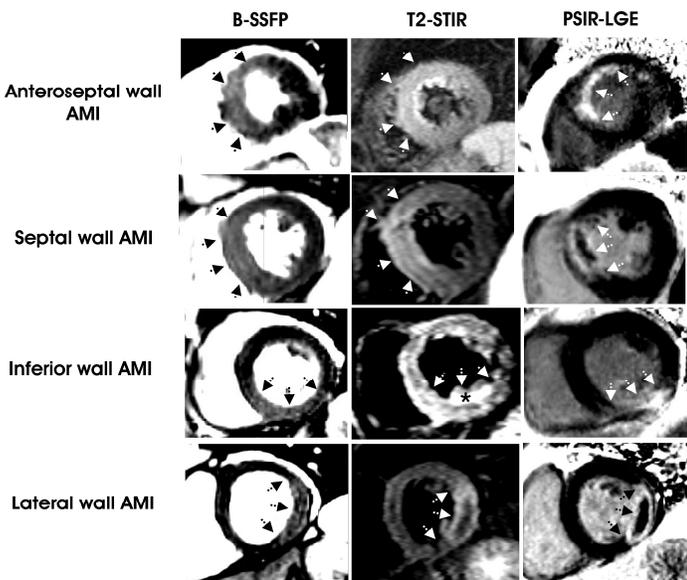
Myocardial edema imaging is usually performed using T2-weighted STIR imaging. Given that balanced SSFP (b-SSFP) imaging methods are sensitive to relaxation changes as well as magnetization transfer effects from increased water content in tissues, we hypothesized that conventional cine b-SSFP sequences should also have the sensitivity to detect myocardial edema in acute reperfused ST-elevation myocardial infarction (STEMI). We tested our hypothesis in an animal model with myocardial ischemia reperfusion injury and in patients with STEMI.

## Methods

Mini-pigs (n=13) and patients with acute reperfused STEMI (n=16) were enrolled in the study. In the mini-pigs, myocardial infarction was created by angiographically guided balloon occlusion of the proximal left circumflex coronary artery for ninety minutes. The animals were imaged on day 2 or 3 after experimental ischemia/ reperfusion. For the clinical arm, patients from the coronary care unit were included within four days after successful percutaneous coronary intervention for STEMI. All CMR images were obtained on a 1.5T clinical system (Siemens, Germany), using the following sequences in the short axis orientation (slice thickness 10mm, 0 gap): conventional cine b-SSFP, T2-STIR (patients only), late enhancement (10 min after injection of 0.2mmol/kg Gd-DTPA), applying typical sequence parameters. Semi-quantitative threshold-based image analysis of late enhancement images (LE) identified the infarct region and infarct area was calculated. In the infarction zone and remote myocardium, on corresponding T2-STIR and SSFP images, signal and contrast, as well as the area of edema were measured and compared using paired t-tests and correlation statistics.

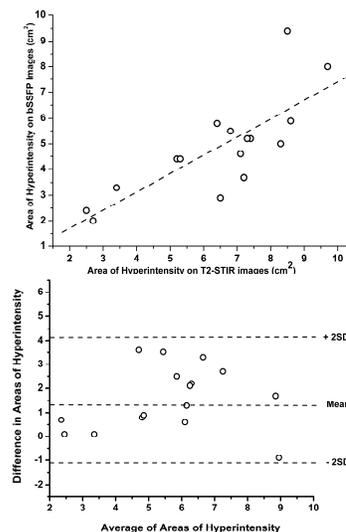
## Results

In the pigs, the area of high b-SSFP signal and the area of LE correlated with  $R=0.83$  ( $p<0.001$ ). Signal intensity in the infarction zone on b-SSFP was higher than in the remote zone ( $203.5 \pm 28.7$  (edema) vs.  $148 \pm 19.8$  (remote),  $p<0.001$ ), with a contrast-to-noise ratio of  $37 \pm 13$ . In the patients (age  $57 \pm 8$  years, 3 female, STEMI location anterior/ septal n= 9, lateral n=1, inferior n=6) on T2-STIR images, the signal intensity in the infarct zone was higher than signal in remote myocardium ( $351 \pm 109$  (edema) vs.  $222 \pm 81$  (remote),  $p<0.001$ ), and the same was observed on b-SSFP ( $252 \pm 35$  (edema) vs.  $163 \pm 32$  (remote),  $p<0.001$ ) (Examples: Figure 1). Contrast-to-noise ratio ( $CNR_{adj}$ ), corrected for voxel size and readout bandwidth, was not different between T2-STIR and b-SSFP ( $CNR_{adj}$  T2-STIR  $77 \pm 37$  vs.  $CNR_{adj}$  b-SSFP  $65 \pm 30$ ,  $p=0.30$ ). The edematous volumes as measured by T2-STIR correlated well with the volumes measured by b-SSFP ( $R=0.78$ ,  $p<0.001$ , Figure 2, upper panel), but on T2-STIR were slightly larger than on b-SSFP (T2-STIR  $6.4 \pm 2.1$  ml vs. SSFP  $4.9 \pm 1.9$  ml,  $p=0.03$ , Bland-Altman Plot Figure 2 lower panel). Infarct volumes on LGE were  $4.2 \pm 1.6$  ml.



## Discussion & Conclusion

We demonstrated that cine b-SSFP could detect edema-related signal in acute reperfused myocardial infarction, in a swine model as well as in patients. In the swine model and in every patient, b-SSFP signal was higher in the infarction zone as compared to remote myocardium. Consistent with myocardial edema and the representation of the area-at-risk, the zone of high signal on b-SSFP was consistently larger than the zone of irreversible injury as assessed by LGE-CMR. B-SSFP may evolve as a novel approach for myocardial edema imaging.



**Figure 1:** Images of patients with reperfused STEMI in different perfusion territories (right column). Myocardial Edema on T2-STIR (middle column) is reflected by an area of hyperintense signal on b-SSFP (left column).

**Figure 2:** Area of hyperintensity, consistent with edema, correlated on T2-STIR and b-SSFP ( $R=0.78$ ,  $p<0.001$ , patient data, upper panel). Areas of hyperintensity on b-SSFP images were slightly smaller than that from T2-STIR (Bland-Altman plot, lower panel).