

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

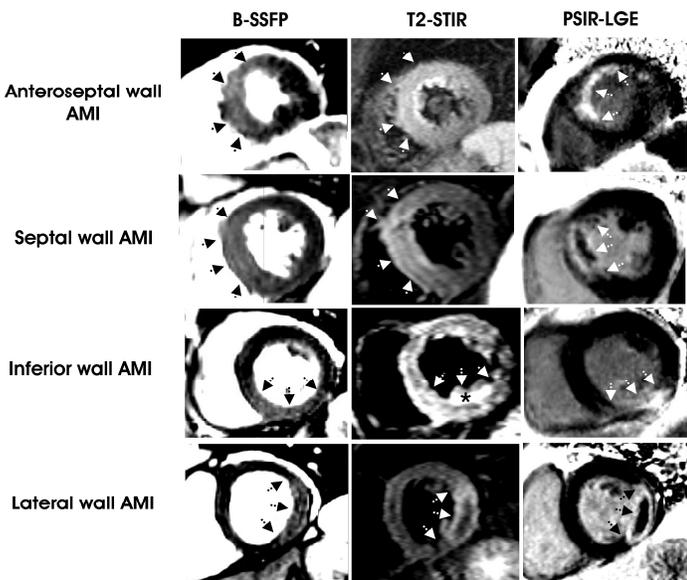
Myocardial edema imaging is usually performed using T2-weighted STIR imaging. Given that balanced SSFP (b-SSFP) imaging methods are sensitive to relaxation changes as well as magnetization transfer effects from increased water content in tissues, we hypothesized that conventional cine b-SSFP sequences 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 ± 28.7 (edema) vs. 148 ± 19.8 (remote), $p<0.001$), with a contrast-to-noise ratio of 37 ± 13 . In the patients (age 57 ± 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 ± 109 (edema) vs. 222 ± 81 (remote), $p<0.001$), and the same was observed on b-SSFP (252 ± 35 (edema) vs. 163 ± 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 ± 37 vs. CNR_{adj} b-SSFP 65 ± 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 ± 2.1 ml vs. SSFP 4.9 ± 1.9 ml, $p=0.03$, Bland-Altman Plot Figure 2 lower panel). Infarct volumes on LGE were 4.2 ± 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.

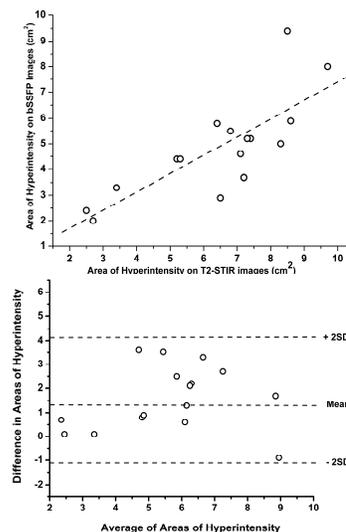


Figure 1: Images of patients with reperfused STEMI in different perfusion territories (right column). Myocardial Edema on T2-STIR (middle column) is reflected by an area of hyperintense signal on b-SSFP (left column).

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).