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T2-prepared SSFP improves diagnostic confidence in edema imaging in acute MI compared with turbo-SpinEcho

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INTRODUCTION

T2-weighted MR imaging of edema in acute MI provides a means for differentiating acute and chronic MI and for assessing the area-at-risk of infarction [1,2]. Conventional T2-weighted imaging of edema uses turbo-SpinEcho (TSE) readout with a dark-blood preparation [3]. Clinical applications of dark-blood TSE methods can be limited by artifacts such as posterior wall signal loss (Fig. 1) due to through-plane motion (Fig. 2) and bright sub-endocardial artifacts due to stagnant blood (Fig. 3) [4].

We hypothesized that single-shot T2-prepared SSFP would be a more reliable method than dark-blood TSE for imaging of edema in patients with MI.

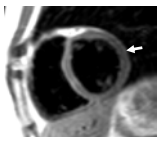


Figure 1. Example dark-blood prepared TSE image with approx. 20% variation in signal intensity for this normal volunteer which is of comparable severity to the variation expected for an acute MI (image is already surface coil corrected).

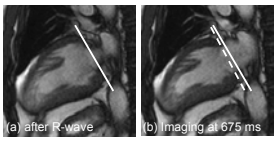


Figure 2. Illustration of through-plane motion that takes place for basal plane between time of dark-blood prep just after R-wave and imaging readout [4].

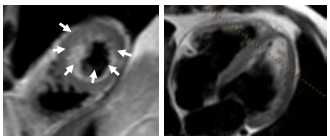


Figure 3. Illustration of stagnant blood artifact in dark-blood prep TSE images.

METHODS

Study Protocol

T2-weighted imaging using both dark-blood TSE and T2-prepared single-shot SSFP was performed on patients within 8 days of acute MI (N=22), and more than 1 year after chronic MI (N=9). The signal uniformity for T2-weighted imaging using both methods was measured for normal volunteers (N=8).

Cardiac Imaging

Experiments were conducted using a 1.5T Siemens Espree widebore imaging system using a custom pulse sequence and image reconstruction software. A T2-prepared single-shot SSFP sequence was used to repetitively acquire an interleaved T2-weighted image and a reference image every 2 R-R intervals (Fig. 1). Single-shot SSFP may be acquired with free-breathing and multiple images may be motion corrected and averaged to enhance SNR [5]. In this study, eight T2-weighted images were acquired over 16 heartbeats.

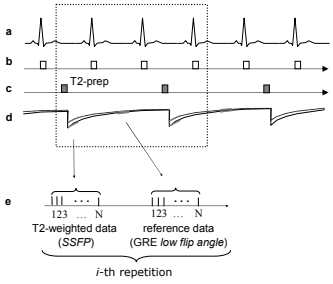


Figure 4. Pulse sequence diagram for T2-prepared single-shot SSFP imaging with acquisition of T2-weighted data and reference data for B1-maps used for parallel imaging auto-calibration and surface coil intensity correction. (a) ECG, (b) R-wave trigger, (c) T2-preparation, (d) magnetization, and (e) data acquisition (during mid-diastole) for i-th repetition.

Dark-blood turbo-spin echo (TSE) imaging used an ECG gated segmented sequence with a double inversion recovery preparation applied immediately following the ECG trigger, and TSE readout in diastole timed to minimize cardiac motion. ECG triggering used 2 R-R intervals between readouts. The dark-blood preparation used a selective component which was 300% of the 6 mm slice-thickness used for imaging. Surface coil intensity correction was performed. TSE images used a bandwidth = 449Hz/pixel, echo-train-length = 25, echo spacing = 4.96 ms, effective TE = 64 ms, with 124 ms imaging duration.

Single-shot T2-prepared SSFP images used a bandwidth = 977Hz/pixel, TE/TR=1.6/3.2 ms, flip angle=90°, T2-preparation TE=60ms. Parallel imaging (rate 2) was used to obtain the full phase encode resolution with an imaging duration of 173 ms in the cardiac cycle. The T2-prepared SSFP imaging sequence used a low flip angle GRE readout with 5° readout flip angle for the proton density reference image.

For both sequences, the in-plane resolution was typically 1.9x2.5 mm2 with 6mm slice-thickness (typical matrix size = 192x108) and rectangular FOV (75%).

Delayed enhancement imaging was performed using a phase sensitive inversion recovery (PSIR) segmented turboFLASH sequence.

Measurements

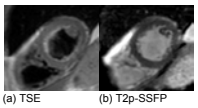
Delayed enhancement images for the acute MI patients were used to determine the coronary territory involvement. The coronary territory corresponding to the region with elevated T2 was determined for each approach blinded to the clinical history or the delayed enhancement images. The coronary territories determined to have edema on each type of T2-weighted image were then compared with the territories with MI to determine the diagnostic accuracy. Images for chronic MI cases were mixed with acute MI cases and assessed at the same time. In the case of chronic MI, regions with apparent elevated T2 were scored as false positives.

RESULTS

Normal Volunteers

In normal volunteers (N=8) where uniform T2-weighted signal intensity was expected, the loss in signal intensity of the posterior wall of the LV (mid-ventricular SAX slice) compared to the septal wall was 22.6±13.7% (mean±SD) using TSE, and 0.6%±4.2% using T2-prepared SSFP. A signal loss of 23% represents a large fraction of the expected difference in signal intensity between acute MI and normal myocardium. Bright stagnant blood artifacts are not an issue with T2p-SSFP approach (Fig. 5).

Figure 5. Stagnant blood artifact in dark-blood prep TSE images (left) are not an issue in bright blood T2p-SSFP approach (right).



Acute MI Patients

In patients with acute MI (N=22), T2-weighted imaging with both methods was performed prior to contrast administration and delayed enhancement imaging of viable myocardium. In all 22 cases, the T2-prepared SSFP was rated to be of diagnostic quality and yielded the correct diagnosis (i.e., 100% agreement with coronary territory involvement as determined from delayed enhancement images). The T2-weighted images using TSE were non-diagnostic in 3-of-22 cases, while 1 additional case rated to be of diagnostic quality had incorrect diagnosis (incorrect coronary territory). Examples images are shown in Figures 6-8.

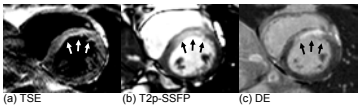


Figure 6. Regions of elevated T2-weighted signal intensity for both the dark-blood TSE and T2-prepared SSFP images are in agreement with the antero-septal acute MI evident in the delayed enhancement image.

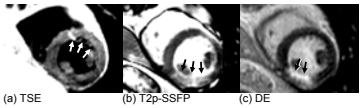


Figure 7. Case of patient with significant R-R variation during the breath-hold. The TSE image (left) has a false positive apparent elevation of T2 in the LAD coronary distribution on images independently judged to be of diagnostic quality. The T2-prepared SSFP (center) with elevated-T2 in RCA territory yielded the correct diagnosis and is in agreement with the delayed enhancement image (right) with an MI in RCA territory.

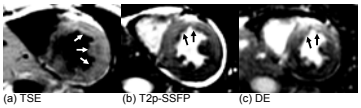


Figure 8. The dark-blood TSE image (left) was judged to be non-diagnostic. The T2-prepared SSFP (center) and delayed enhancement image (right) are in agreement with MI in LAD territory.

Chronic MI Patients

Chronic MI patients (N=9) were imaged according to the same protocol as acute MI patients. In all 9 cases the T2-prepared SSFP was rated to be of diagnostic quality and yielded the correct diagnosis (i.e. no apparent edema). In the case of dark-blood TSE, there were 5 false positive cases with apparent edema, with 3 suggesting abnormalities in the LAD territory and 2 in both the LAD and RCA territory. Example images for chronic MI are shown for cases with correct diagnosis (Fig. 8) and a false positive case (Fig. 9).

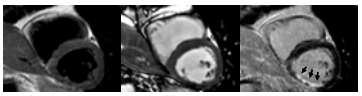


Figure 9. Case of chronic MI in RCA territory with true negative for both TSE (left) and T2p-SSFP (center).

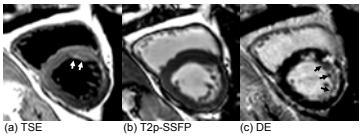


Figure 10. Case of chronic MI in LAD territory with false positive for TSE (left) and true negative for T2p-SSFP (center).

SUMMARY & CONCLUSIONS

The proposed T2-prepared SSFP bright blood approach overcomes artifacts such as posterior wall signal loss due to cardiac motion and bright sub-endocardial rims due to stagnant blood that occur with widely used dark-blood TSE methods, thereby improving the diagnostic quality (Fig. 11). The TSE method was sensitive to RR variation and image quality suffered at higher heart rates, whereas the single shot T2-prepared SSFP approach was robust to such variation and enabled non-breathhold imaging. T2-prepared SSFP may be used clinically for reliable T2-weighted imaging in acute MI.

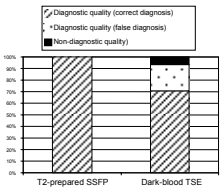


Figure 11. The dark-blood TSE method was found to provide diagnostic quality imaging with a correct diagnosis in only 72% of the cases (acute and chronic combined) while the T2-prepared SSFP was diagnostic quality and correct in 100% of the patients.

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