Accelerated Phase Sensitive Inversion Recovery for Detecting Myocardial Infarction using Gd-DTPA Delayed Hyperenhancement

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INTRODUCTION

Following administration of gadolinium, infarcted myocardium exhibits delayed hyperenhancement and can be imaged using an inversion recovery (IR) gradient recalled echo sequence. Phase sensitive reconstructed IR has a number of benefits [1] including consistent contrast and appearance over a relatively wide range of inversion recovery times (TI), improved contrast-to-noise ratio, and consistent size of hyperenhanced region. The imaging time may be accelerated by acquiring fewer phase encodes using partial-Fourier and/or sensitivity encoding (SENSE [2]) methods. We present and compare experimental results for both methods. The acceleration may be used to either reduce breath-hold duration or increase spatial resolution for a fixed breath-hold time.

METHODS

Phase sensitive cardiac imaging poses unique challenges due to the combination of field inhomogeneity, motion, and low SNR, which make it difficult to obtain a reliable estimate of the background phase. The approach we have taken is to obtain a background reference image at the same cardiac phase, during the same breath-hold acquisition. Using Gd-DTPA, the inversion recovery acquisition sequence requires 2 heart beats for almost full magnetization recovery. Therefore, it is possible to acquire the reference image during alternate heart beats without increasing the breath-hold duration. This type of acquisition provides a reference image with high spatial resolution and eliminates mis-registration errors due to motion. The reference image is used to estimate both the background phase and surface coil field maps.

The surface coil field maps derived from the reference images were used for optimal B1-weighted combining [3], and for SENSE processing [2] in the case of reduced FOV acquisitions. By applying the same B1-weighted complex combining to both T1-weighted IR and reference image, any phase error in the B1-maps was cancelled in the phase sensitive (homodyne) image. All images were surface coil intensity normalized based on the reference magnitude image.

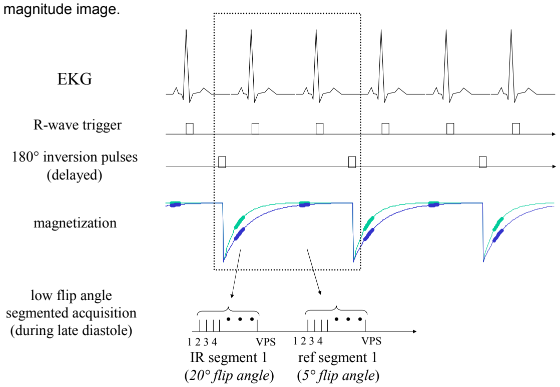

Figure 1. Pulse sequence diagram for gated, segmented *k*-space acquisition of IR and reference images using low flip-angle readouts. Data for IR and reference images are collected alternately every other heartbeat.

Table 1 Imaging Parameters

scanner:	GE Signa 1.5T
pulse sequence:	Fast Gradient Recalled Echo
k-space acquisition:	ECG Gated, Segmented, Interleaved
coils:	4-element cardiac phased array
resolution:	256 freq x 96 phase encodes
TR:	7.9 ms
views per segment (VPS):	16
segment duration:	126 ms
bandwidth:	±31.25 kHz
heart beats/segment:	2
breath-hold duration:	12 heart beats
slice thickness:	8 mm

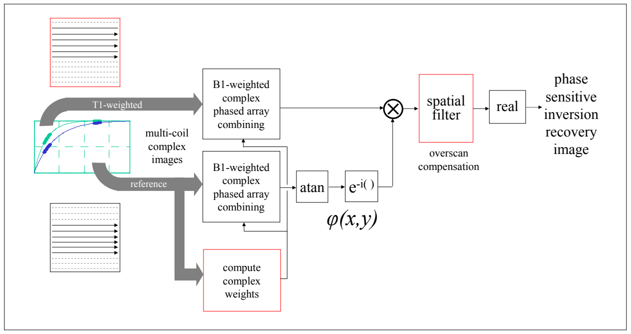

Figure 2. Block diagram showing the phased-array phase-sensitive reconstruction of partial *k*-space IR image using a separate full *k*-space(1/2 y-resolution) reference image acquired after magnetization recovery.

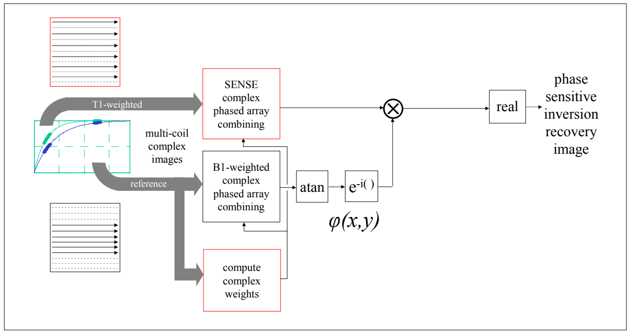

Figure 3. Block diagram showing the phased-array phase-sensitive SENSE accelerated reconstruction of IR image using a separate reference image acquired after magnetization recovery.

RESULTS

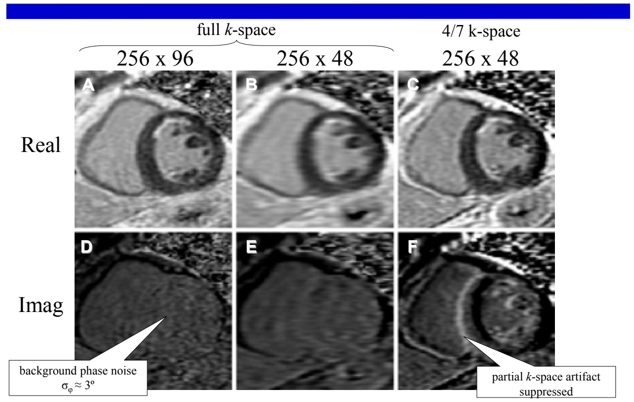

Figure 4. SAX slice images comparing real (top row) and imaginary (bottom row) components for full and partial *k*-space acquisitions. Imaginary images (D) and (E) corresponding to full *k*-space acquisition contain essentially noise ($\sigma_\varphi \approx 3°$). Imaginary image (F) corresponding to partial *k*-space acquisition contains large edge artifacts which are not present in real image (C).

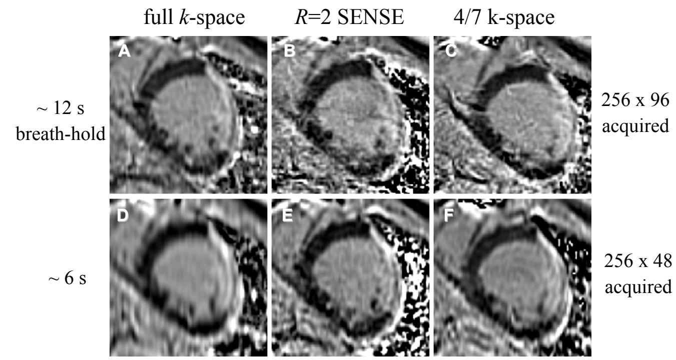

Figure 5. Comparison of short axis images reconstructed from full *k*-space acquisition (left column) and *R*=2 accelerated imaging using SENSE (center column) and partial *k*-space (right column) for 96 lines acquired (top row) and 48 lines (bottom row). Note that the spatial resolution of images (E) and (F) are comparable to (A) with ½ the breath-hold duration. The images in (B) and (C) have 2x the spatial resolution as (A) in the same breath-hold duration.

DISCUSSION

- SENSE Method
  - g-factor related SNR loss
    - approx. 30% for 4 coils (< 5% for 8 coils)
  - more sensitive to localizing for best in-plane rotation and to avoid wrap (canceling wrap increases g-factor loss)
- Partial *k*-space Method
  - combined partial-*NEX* & inversion recovery
    - point spread function (PSF) may cause edge artifacts (dependent on TI)
    - artifacts minimized using smaller acquisition window
  - combined partial-*echo* & inversion recovery
    - has negligible artifacts

CONCLUSIONS

- R=2 acceleration of phase sensitive IR imaging possible using SENSE or partial *k*-space
- reduced breath-hold duration or improved spatial resolution
- can be combined with multi-slice phase sensitive IR for single breath-hold 8 slice SAX stack (*see poster 1637*)

REFERENCES

1. Kellman P, Arai AE, McVeigh ER, Aletras A.H., Phase Sensitive Inversion Recovery for Detecting Myocardial Infarction using Gadolinium Delayed Hyperenhancement. *Magn. Reson. Med.*, 47(2), 372-83, 2002.
2. Pruessmann P, Weiger M, Scheidegger MB, Boesiger P, SENSE: Sensitivity Encoding for Fast MRI. *Magn. Reson. Med.*, 42(5), 952–62, 1999.
3. Roemer, P.B., et.al., *Magn. Reson. Med.*, 16, 192-225, 1990.