Navigator guided High-Resolution Single-Shot Black-Blood TSE images using ZOOM and Sensitivity Encoding (SENSE) on a 32 channel RF system

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Introduction: In current clinical practice, a dual –inversion prepared turbo-spin echo sequence (BB-TSE) is used for tissue characterization of the myocardium. In BB-TSE a single slice is acquired during suspended respiration of 12-16 s. In several clinical instances, BB-TSE images are acquired in multiple orientations and the resulting long acquisition time leads to: 1) patient discomfort; 2) increased examination time; 3) limited coverage; and 4) motion artifacts. While traditional Single-shot TSE (BB-SSh) readouts are technically feasible, and can substantially minimize these adverse effects, the spatial resolution of such BB-SSh images is intrinsically limited by the T_2 decay during the long readout duration. We hypothesize that this intrinsic loss of resolution associated with SSh readout can be minimized by a combination of: (1) restricting the field-of-view (FOV) of the imaging volume to the heart by applying the 90° and the 180° pulses of the TSE readout in orthogonal directions (ZOOM), and (2) using a 32 channel coil capable of applying the Sensitvity Encoding (SENSE) along direction of the restricted FOV independent of the orientation. The purpose of this work is to present the theoretical and experimental verification of this hypothesis in normal subjects.

Materials and Methods: The effect of the blurring due to readout duration was evaluated using numerical simulations. Eight (6m/2f, age: 36 yrs: range 28-55) normal subjects with no history of heart disease were imaged on a 1.5T MR scanner (Achieva, Philips Healthcare), with vector-cardiographic gating (VCG). A 32 channel surface coil was used for signal reception.

MR Sequences: Three SSh-TSE sequences with identical acquired voxel size (1.5x2.0x8.0 mm^3), TR/Effective TE (∞/80 ms), and bandwidth per pixel (500 Hz) were used to acquire BB-TSE images of the heart in short-axis, and long axis orientations. The length of the readout of each of the sequences were as follows: SSh: 429 ms (TSE factor: 109); SSh-SENSE: 257 ms (TSE factor: 65); SSh-SENSE+ZOOM: 160 ms (TSE factor: 41). The half-scan factor was adjusted to yield the same EffTE for all three SSh sequences, and respiratory navigator triggering was used to acquire data during free breathing. For comparison, a multi-shot, TSE sequence with a readout duration of 155 ms (TSE factor 29), was acquired over a breath-hold duration of 14-16 hb.

Analysis: Image quality was graded by an experience observer for the following metrics on a scale of 1-4 : (a) blood signal suppression (1: Prominent slow-flow; 2: Moderate slow flow; 3: Almost no slow flow; 4: No visible slow flow), (b) signal intensity and sharpness of the myocardium (1: Poor – patch/heterogenous signal; 2: Intermediate (some patchiness); 3: Minimal heterogeneity; 4: None observable), and (c) motion artifacts (1: Significant; 2: Moderate: 3:Little or none; 4: None).

Results: Representative T2-wtd BB TSE images acquired using the SSh, SSh-SENSE, and SSh-SENSE+ZOOM are shown in Figure 1, and the results from numerical simulations are shown in Figure 2. Image quality metrics revealed that SSh-SENSE+ZOOM images performed better than the other two methods, and the quantitative metrics of SSh-SENSE+ZOOM images were closer to the conventional multi-shot MSh-BB-TSE sequence (Table 1).

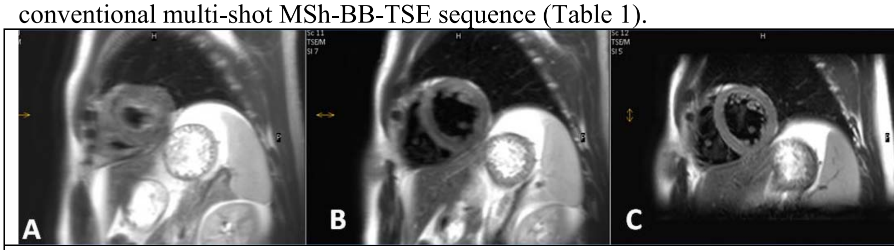

Figure 1: Comparison of SSh BB-TSE images acquired with identical prescribed spatial resolution of 1.5x2.0x8.0 mm^3 and EffTE/TR: 80 ms/∞. (A) SSh with a readout duration of 429 ms introduces significant blurring; (B) SSh+SENSE, with a readout duration of 257 ms reduces blurring substantially ; (C) SSh-SENSE+ZOOM with a readout duration of 160 ms; The phase encoding direction is indicated by the arrow. Note that ZOOM makes it possible to have the phase encoding direction in FH direction (C), and the redundancy of coils in the FH direction (32 channel array) also allows one to use SENSE along the same direction. The combination of the two approaches results in a substantial reduction in the readout duration yielding higher image quality.

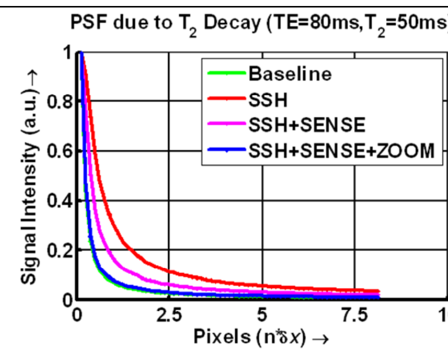

Figure 2: Numerical simulations demonstrating the effect of loss of resolution with longer readouts.

Table1: Assessment of Image quality

Sequence	SSh			SSh-SENSE			SSh-SENSE+ZOOM		
Criteria	Blood Signal Suppression	Myocardial Sharpness	Lack of Artifacts	Blood Signal Suppression	Myocardial Sharpness	Lack of Artifacts	Blood Signal Suppression	Myocardial Sharpness	Lack of Artifacts
$T_{2\ wtd}$ BB Imaging	2.9	2.1	3.4	3.1	1.9	3.9	3.7	2.9	3.7

Discussion: 32 channel coils provide the ability to apply SENSE along all three directions (RL, FH, and AP). This flexibility coupled with the ZOOM approach can be exploited to substantially reduce the read-out duration for SSh-TSE sequences, and preserve the spatial resolution. Unlike SENSE, the reduction of readout duration using ZOOM does not entail an SNR penalty.

Conclusions: Our results show that it is feasible to develop a free breathing T_2 weighted BB Single shot TSE images of the myocardium with image quality that is comparable to conventional BB-TSE sequence.