Accelerated Black Blood Imaging Using Self-Calibrated Split-Echo FSE (SCSE-FSE) Imaging

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Introduction: In current clinical practice black blood prepared fast spin echo (FSE) techniques [1] are used for **(i)** imaging anatomy/morphology of the heart and large vessels [2], **(ii)** for detection of edema [3], **(iii)** for adding diagnostic confidence to the assessment of amyloidosis [4] and (iv) for T_2* weighting/mapping based tissue characterization [5]. With 8 to 10 short axis slices required to cover the entire heart FSE based black blood imaging can be time consuming since it is commonly confined to a single slice per breath-hold. Parallel imaging can overcome these constraints by affording a strategy that employs accelerated 2D black blood FSE with the ultimate goal to encompass 3-4 slices per breath-hold. This strategy is conceptually appealing for the pursuit of comprehensive heart coverage in clinically acceptable examination times. To accomplish this goal, this study (i) proposes an accelerated FSE technique that uses a split-echo approach for self-calibrated parallel imaging and (ii) examines the applicability of accelerated FSE imaging for double and triple inversion recovery prepared imaging of the heart. For comparison, conventional double and triple IR prepared FSE is applied.

Methods: A self-calibrated split-echo FSE (SCSE-FSE) technique (matrix size=512x256, echo train length=16, number of dummy echoes=8, in-plane resolution=(1.3 x 1.3) mm^2, slice thickness=5 mm, TE=67 ms, TR=1 R-R intervals, inter-echo time 4.19 ms, receiver bandwidth 673 Hz/pixel) was proposed and implemented as illustrated in Fig 1. Extra displacement gradients were incorporated along the read-out direction to shift odd and even echoes groups apart [6]. Two sets of independent phase encoding schemes were applied for the odd and even echo group. One echo group was used to acquire calibration scans for the estimation of the component coil sensitivity maps (Fig 2). This approach makes an external reference scan obsolete and hence can be considered to be a self-calibrating approach. The other echo group was used to generate undersampled data sets. Net acceleration factors ranging from R=2 to R=**4** were used. The SCSE-FSE imaging module was combined with double IR for blood suppression and triple IR preparation for blood/fat suppression.

Imaging was conducted on a 3.0 T whole body system (Siemens Verio, Siemens Healthcare, Erlangen) using a body coil for TX and a 32-channel cardiac coil array (IN VIVO Corp., Gainsville, USA) for RX. An MR stethoscope (easyACT, MRI.TOOLS GmbH) was used for cardiac triggering. Data acquisition was performed during diastole. SENSE reconstruction [7] was employed to unfold undersampled data sets.

Results: Black blood prepared SCSE-FSE imaging using acceleration factors of up to R=4 was successfully performed in all subjects. Representative short axis and four chamber views of the heart derived from double and triple inversion recovery SCSE-FSE are shown in Figure 3 derived from unaccelerated, 2-fold 3-fold and 4-fold accelerated imaging.

It took 18 heartbeats to acquire the conventional FSE images compared with only 7 heartbeats to acquire the 4-fold accelerated SCSE-FSE images. The SCSE-FSE technique has no effect on blood suppression.

These examples demonstrate that image quality, myocardial boarder delineation, signal to noise ratio and blood/fat suppression are suitable for clinical applications.

Discussion and Conclusions: The feasibility of accelerated black blood FSE imaging has been demonstrated. SCSE-FSE based cardiac imaging holds the promise to potentially obviate the need for separate reference scans which are acquired prior to accelerated imaging and hence come with the caveat that misregistration between calibration scans and accelerated scans might occur in the presence of patient or physiological motion. Self-calibration is conveniently incorporated into SCSE-FSE with no sacrifice in scan time or no compromise in the net acceleration factor. SCSE-FSE comes with no extra noise amplification due to the use of irregular undersampling patterns commonly used in conventional self-calibration techniques. The accelerated FSE approach presented here promises to extend the capabilities of routine black blood imaging from a single slice to multiple slices per BH. One practical implication is that SCSE-FSE reduces examination times while improving both operator convenience and patient comfort. A recognized limitation of this feasibility study is its assessment in a limited number of healthy subjects. Therefore, efficacy of the described accelerated FSE approach in the clinical routine environment awaits further study. In conclusion, we anticipate the extension of this work to examine its applicability for accelerated myocardial T_2* mapping and to evolve towards accelerated diffusion weighted imaging of the heart.

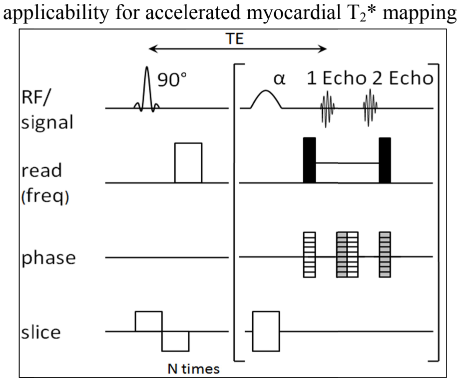

FIG 1. Basic scheme of the self-calibrated split echo FSE (SCSE-FSE) technique. Unlike conventional FSE odd and even echoes groups are splitted and independently phase encoded.

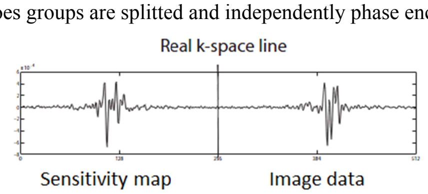

FIG 2. Zoomed view of a k-space line to illustrate the split echo approach. Both echo groups are phase encoded and handled independently. One echo group is used to generate the coil senstivity map. The other group is used to generate undersampled data.

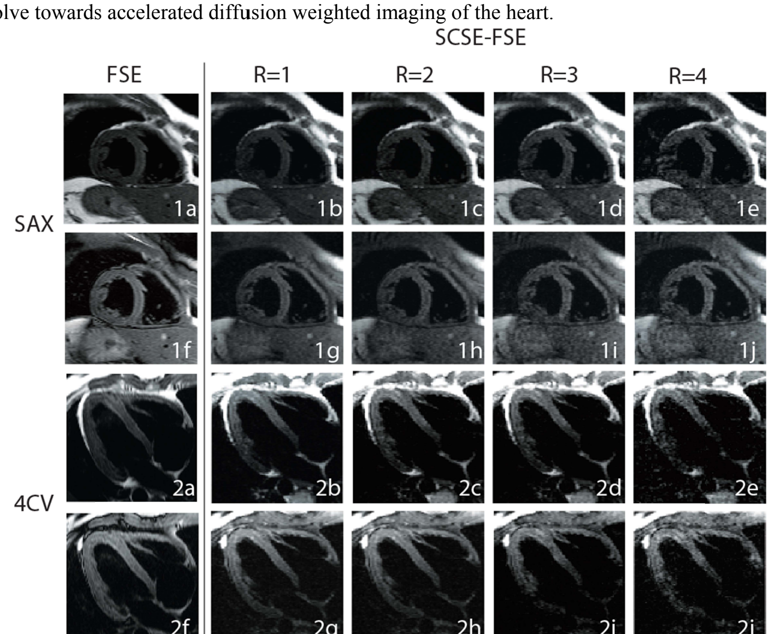

FIG 3. Comparison of conventional FSE and SCSE-FSE, **1a-1e)** short axis view (double IR), **2a-2e)** four chamber view (double IR), **1f-1j)** short axis view (triple IR) **2f-2j)** four chamber view (triple IR) **a,f)** conventional FSE **b-e,g-j)** prepared images derived from SCSE-FSE data sets using reduction factors of R=1, 2, 3, 4.

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