**Ultrashort Echo Time (UTE) Imaging With a Time Frame Regularized Compressive Sensing (TF-CS)**

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## INTRODUCTION

There is increased interest in ultrashort echo time (UTE) imaging which has the potential to image and quantify tissues or tissue components which are "invisible" when using conventional clinical magnetic resonance imaging (MRI) sequences [1]. Regular two-dimensional (2D) UTE imaging sequences employ half pulse excitations followed by radial ramp sampling. The 2D UTE sequence requires the summation of two acquisitions: one with a positive slice selective gradient and the other with a negative slice selective gradient to form a slice [1]. This adds a significant penalty to the total scan time. 3D UTE imaging employs a short rectangular pulse excitation followed by 3D radial ramp sampling, which is even more time consuming [2]. Both 2D and 3D UTE sequences typically require undersampling to reduce scan time, but this produces streak artifacts. Recent advances in compressive sensing (CS) permits data recovery from extremely under-sampled measurements [3-5]. It is expected that the application of these techniques with UTE methods could greatly reduce the number of measurements required and hence accelerate data acquisition. In this study we aimed to reconstruct UTE image from the understampled data using a tight-frame (TF) regularized compressive sensing (TF-CS) technique [6].

## Theory

$$u = \operatorname{argmin}_u \frac{1}{2} | MFu - y |_2^2 + \mu | Du |_1 \quad [1]$$

In the TF-CS reconstruction algorithm, the image is reconstructed by solving an optimization problem as shown in Equation [1], where $F$ is the Fourier transform, $M$ is the downsampling operator, and $D$ is an operator that decomposes the image u onto the TF basis which is an overcomplete wavelet basis[4]. An advantage of this TF approach over other commonly used regularization methods, such as total variation (TV) [7], have been demonstrated in a variety of image processing problems, including CT reconstructions [6]. Once the optimization model is designed, it can be solved via the Split Bregman algorithm [8], which is an iterative algorithm that is particularly suitable for CS problems of this kind.

## MATERIALS AND METHODS

The TF-CS algorithm was applied to 2D UTE imaging of a GE phantom with long T2* and a piece of cadaveric human cortical bone (tibial mid-shaft) with an extremely short T2* using a 3T General Electric (GE) whole-body scanner. The 2D UTE imaging protocol for cortical bone used the following parameters: TR = 200 ms, field of view (FOV) = 8 cm, matrix = 256×256, slice thickness = 5 mm, band width = 125 kHz, TE = 8 us, five different degrees of undersampling (the number of projections = 800, 400, 200, 100 and 50, corresponding to an undersampling factor of 1, 2, 4, 8 and 16, respectively). For the GE phantom study, FOV was increased to 20 mm. The 2D UTE data were reconstructed with the TF-CS algorithm as well as the GE production re-gridding reconstruction algorithm.

## RESULTS AND DISCUSSION

In our preliminary studies, 2D MRI images were successfully reconstructed from heavily undersampled UTE acquisitions. Promising results with much suppressed streaking artifacts compared to standard FFT based-reconstruction approaches were observed, as shown in Figure 1, which shows 2D UTE imaging with 100 half projections (corresponding to an undersampling factor of 8) of the long T2 GE phantom and the short T2 bone sample with GE product re-gridding reconstruction (A, C) and 2D TF-CS reconstruction (B, D). This shows marked streaks reduction with the TF-CS algorithm. Even more dramatic streaks reduction is expected with 3D UTE compressed sensing reconstruction which will be our next step. Computer graphics processing units (GPUs) together with a multi-resolution reconstruction scheme will be used to speed up the reconstruction since a much higher computational burden is expected with the 3D problem [6].

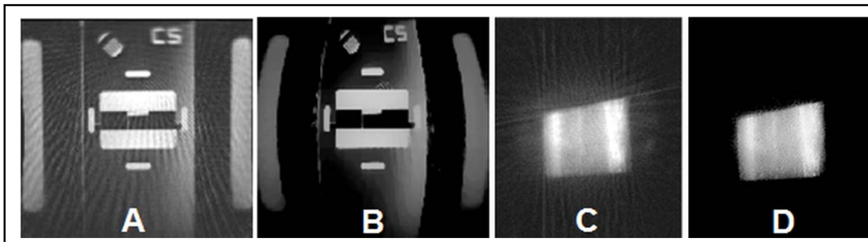


***Fig 1*** *2D UTE imaging of a phantom with GE product re-gridding reconstruction (A) and TF-CS reconstruction (B), and a cortical bone sample with GE product re-gridding reconstruction (C) and TF-CS reconstruction (D). There is a drastic reduction in streak artifact with TF-CS reconstruction. Spatial distortion in (B) is due to gradient non-linearity and can be corrected through gradient de-warping (to be implemented for TF-CS).*

## CONCLUSIONS

These results show that TF-CS reconstruction can significantly speed up data acquisition and reduce undersampling streak artifacts. This novel reconstruction algorithm may help developing translational 2D and 3D UTE imaging techniques.

## REFERENCES

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