Imaging of the Knee using 3D Fast Spin Echo with Compressed Sensing

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Target audience: Physicists and clinicians interested in fast musculoskeletal imaging

Purpose

Proton density (PD)-weighted fast spin echo MR imaging allows for excellent depiction of menisci, cruciates, and articular cartilage. With the addition of fat saturation (FS), the bone marrow contrast can be improved, at the expense of an increase in scan time. Generally, a multi-slice 2D FS PD sequence is the preferred choice to a 3D PD FS due to the relatively long scan times (5-6 minutes) associated with the 3D scan. The benefit of a 3D sequence can be an increase in signal-to-noise as well as larger coverage and an isotropic data set, provided there is no patient related motion artefact. We have evaluated the combination of compressed sensing (CS) with a 3D PD FS Fast Spin Echo acquisition to reduce acquisition times.

Method

Following ethical approval and informed consent, 12 asymptomatic knees were imaged in 7 volunteers (5 male and 2 female between 24 and 56 years old) were imaged at 3.0 T (Discovery MR750, GE Healthcare, Waukesha, WI) using an 8-channel transmit/receive knee coil. A PD FS 3D FSE sequence was modified to perform random CS undersampling followed by a custom reconstruction algorithm written in MATLAB (The Mathworks, Natick, MA). For the CS, randomly undersampled k-space data are first processed with CS to give aliased images for each coil that would result from uniformly undersampled k-space data. The aliased images are then Fourier transformed to give uniformly undersampled k-space data for each coil. Finally the k-space data are processed with normal ARC[1] processing to give the final image (Figure 1). The CS reconstruction algorithm used a conjugate gradient solver with 15 iterations to find an image with the minimum L1 norm of its gradient for each coil.[2] The reference imaging sequence was a sagittal 3D FSE with extended echo train (CUBE, GE Healthcare)[3] with the following parameters: TE/TR = 30/1500ms, ETL = 60, Matrix = 256x256, FOV = 160mm x 160mm, Slice thickness = 1 mm, ARC acceleration = 2x1 with an acquisition time of 5 minutes 23 seconds. The acquisition was then repeated using identical parameters but with CS using an acceleration factor of two, resulting in a scan time of 2 minutes 40 seconds.

The individual reference and CS images for each knee were compared on an Osirix workstation (Pixmeo, Geneva) for image artefacts, visibility of menisci, cruciates and articular cartilage using 5 point scales (where 5=excellent depiction or no artefacts and <3 considered non-diagnostic). They also rated the sets for diagnostic information as either equivalent or which set was considered the best.

Results

All the images of all knees were considered of diagnostic quality. Mild heterogeneity artefact was recorded in 6/12 CS studies and moderate in 1/12 the remainder had no artefact. Mild artefact was recorded in 3/12 standard studies the others had no artefact. The menisci and bone marrow were rated excellent in all knees of both datasets, the cruciates and articular cartilage excellent in all the standard studies and in 10/12 CS studies with other two rated "good". Overall the studies were considered "equal" for diagnostic information in 9 of the 12 studies with the standard study rated better in 3/12.

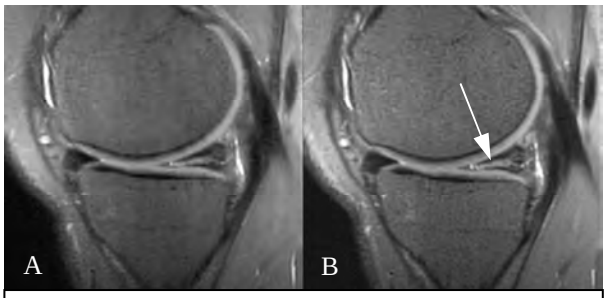

Figure 1: (A) CS sequence obtained in half the time of (B) Standard 3DFSE CUBE. Note similar delineation of the asymptomatic lateral meniscus tear (arrow)

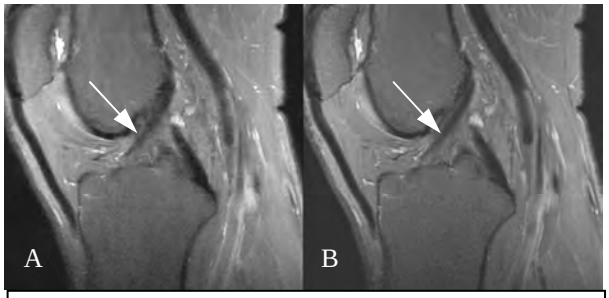

Figure 2: (A) CS sequence, (B) Standard 3DFSE CUBE. In this knee the anterior cruciate (arrow) was considered less well demonstrated in the CS image but still of diagnostic quality

Discussion

Overall the CS acquisition proved very comparable with the standard acquisition and provided diagnostic quality images in half the standard acquisition time. Minor variations were noted in relation to the anterior cruciate and articular cartilage visibility as well as mild bone marrow heterogeneity – all of which could be related to undersampling.

Conclusion

This work indicates that diagnostic quality compressed sensing 3D PD FS imaging of the knee can be performed in 2-3 minutes.

References

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