IMAGING OF THE MOVING WRIST USING RAPID UNDERSAMPLED K-SPACE ACQUISITION WITH ITERATIVE RECONSTRUCTION

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Target audience: This abstract will benefit imaging scientists working on the clinical application of reduced k-space acquisition pulse sequences and cost-function based image reconstruction methods, and musculoskeletal radiologists interested in the use of rapid MRI to advance understanding of the structure and function of complicated joints such as the wrist.

Purpose: Dynamic instability of the wrist, occurring during normal unassisted motion, is a complex condition that has increased importance in musculoskeletal medicine. The objectives of this study were to develop an MRI protocol for evaluating the wrist during continuous and realistic unassisted motion, and to demonstrate that the resulting anatomical images enable the measurement of metrics commonly evaluated for dynamic wrist instability. Dynamic images during realistic wrist movement were acquired to visualize the bones and joint spaces, and measure interarticular distances at optimal points in space and time using Siemens' CV_Sparse[1] and LiveView[2] Works-In-Progress sequences.

Methods: An "active MRI" protocol was developed using a bSSFP sequence (True FISP) with slow 475 ms temporal resolution. Fifteen wrists of 10 asymptomatic volunteers were scanned during supination/pronation, radial/ulnar deviation, "clenched-fist", and volarflexion/dorsiflexion maneuvers. Two physicians evaluated distal radioulnar joint (DRUJ) congruity, extensor carpi ulnaris (ECU) tendon translation, the scapholunate (SL) interval or gap (see Fig 1), and the SL, radiolunate (RL) and capitolunate (CL) angles from the images. We also implemented 3D True FISP with 10-slice acquisition and 5 second temporal resolution, but this required the patient to move the wrist in an unrealistic, slow motion (60 s per cycle) to prevent artifacts. We then implemented high temporal resolution CV_Sparse and LiveView: 1. Undersampled Cartesian K-space acquisition with iterative sliding window cost function based iterative reconstruction (using CV_Sparse) at 50 ms per slice, and 2. Undersampled Radial k-space acquisition with sliding window (MFSW) or non-linear cost function-based iterative reconstruction (CS-NOIR) using LiveView (see Fig. 2), at 74 ms or higher per slice. All studies were performed on a Siemens 3T Trio Tim MRI system (VB17A) or 3T Skyra MRI System (VD11D).

Results: As one example, mean and extrema measurements taken from the dynamic images are illustrated in Fig. 1. The LiveView radial acquisition was evaluated with realistic motion of the wrist of approximately one cycle of ulnar-radial deviation every 2 seconds. This more rapid motion provided more assurance that abnormal relative motion of the wrist bones would be induced during the dynamic imaging.

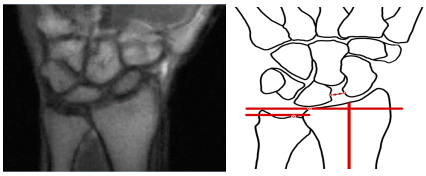

Fig 1: SL gap (two-sided arrow) and **ulnar variance** (distance between the dots with white centers on the solid red lines). The solid red lines represent the most distal aspect of the distal ulna and most proximal aspect of distal radius.

Discussion: Although not all shown here, joint measurements obtained were in agreement with values reported in the literature for normal subjects. Rapıd acquisition in the presence of realistic motion provided assurance that abnormal movements of the bones would be visualized.

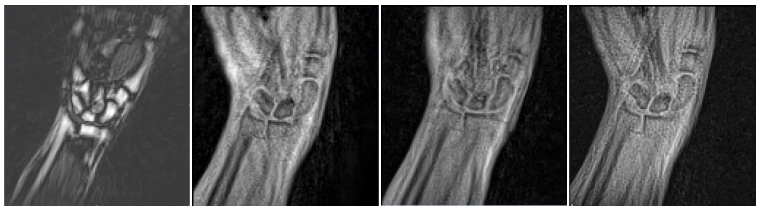

Fig 2: a. Radial-TrueFISP b. Radial-FLASH c. Radial-FLASH d. Radial-FLASH

Voxel Size (mm x mm x mm (slice))	1.33 x 1.33 x 6.0	1.42 x 1.42 x 6.0	1.025 x 1.025 x 6.0	1.42 x 1.42 x 6.0
Field of View (Freq x Phase) (mm x mm)	170 x 170	128 x 128	128 x 128	128 x 128
Base Resolution (Freq x Phase)	125 x 125	90 x 90	125 x 125	90 x 90
TR (ms) : TE (ms)	2.96 : 1.48	4.11 : 2.35	4.11 : 2.35	4.11 : 2.35
Temporal Phases	496 in 36.63 s	49 in 5.18 s	71 in 7.19 s	495 in 36.63 s
Temporal Frames per second	13.5	13.5	9.87	13.5
Temporal Resolution (ms per image)	74	74	102.75	74
Radial K-space lines per Group	25	18	25	18
Number of Groups per Image	5	5	5	5
Bandwidth	1115	420	420	420
Flip Angle (degrees)	28	4	4	4
Image Reconstruction	MFSW	CS-NOIR	CS-NOIR	MFSW

Conclusion: Additional work is underway to assess the use of these methods as a supplement to conventional static joint imaging, and for correlating the motion MRI metrics with arthroscopic or surgical findings, and with MR arthrography and dynamic CT.

References: 1. CV_Sparse: Triggered 2D real-time CINE featuring compressed sensing and k-t regularization (Works-in-Progress), SIEMENS Application Guide, Release 760, November 2012. 2. LiveView Sequence (Works-in-Progress), SIEMENS Application Guide, Release 610, August 2011.

Acknowledgement: The authors acknowledge the support and critical contributions of Tobias Block PhD, Sinyeob Ahn PhD, and Gerhard Laub PhD, of Siemens Healthcare, Inc.