Evaluation of the Articular Cartilage of the Wrist Joint Using Two-Dimensional and Three-Dimensional Sequences at 1.5T and 3T

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Purpose: Detecting cartilage lesions within the wrist joint with magnetic resonance (MR) imaging is challenging due to the thin articular cartilage and complex surface geometry of the distal radius and carpal bones. The use of high field strength scanners, dedicated multi-channel coils, and three-dimensional sequences may potentially improve diagnostic performance. This study was performed to compare various two-dimensional and three dimensional MR sequences at 1.5T and 3T for evaluating the articular cartilage in human cadaveric wrist joints.

Methods: An MR examination was performed on 5 fresh frozen human cadaveric wrist joints using a 1.5T scanner (Signal Excite HdX, GE Healthcare, Waukesha, WI) and 3T scanner (Discovery MR750, GE Healthcare, Waukesha, WI) and an 8-channel phased-array extremity coil. All MR examinations consisted of coronal fat-saturated proton density-weighted fast spin-echo (PDFS) sequences (TR/TE:2000/28ms, 0.3 x 0.3 x 2.0 voxel size, 2.7 minute scan time), fat-saturated T2-weighted fast spin-echo (T2FS) sequences (TR/TE:3000/83ms, 0.3 x 0.3 x 2.0 mm voxel size, 5.6 minute scan time), and fat-saturated FSE-Cube sequences (TR/TE:2000/37ms, 0.4 x 0.4 x 0.4 mm voxel size, 8.5 minute scan time) performed at both 1.5T and 3T and a fat-saturated Multiple Echo Recombined Gradient-Echo (MERGE) sequence (TR/TE:38/14ms, 5° flip angle, 0.3 mm x 0.4 mm x 1.0 mm voxel size, 6.2 minute scan time) and fat-saturated ultraFast Gradient-Echo (FGRE) sequence (TR/TE:15/7ms, 20° flip angle, 0.3 x 0.4 x 1.0 mm voxel size, 7.4 minute scan time) performed at 3T. Signal-to-noise ratio (SNR) and contrast-to-noise (CNR) measurements were performed on all MR examinations. Paired t-tests were used to compare differences in SNR and CNR values between sequences. Two musculoskeletal radiologists independently used all sequences at separate sittings to detect cartilage lesions on each articular surface of the wrist joint. The radiologists also ranked the sequences according to the following subjective criteria of image quality: clarity of articular surface, conspicuity of cartilage lesions, tissue contrast, and overall image quality. Using arthroscopy performed by an experienced orthopedic wrist surgeon as the reference standard, the sensitivity, specificity, and accuracy of each sequence for detecting 25 cartilage lesions (12 Outerbridge grade 1 and 13 Outbridge grade 2) on the 90 articular surfaces in the 5 cadaveric wrist joints was determined. Kappa statistic was used to measure interobserver variability between readers for determining the presence or absence of cartilage lesions.

Results: On subjective analysis, reader confidence was higher at 3T than at 1.5T and FGRE at 3T received the highest rank for clarity of articular surface, conspicuity of cartilage lesions, tissue contrast, and overall image quality (Figure 1). FGRE at 3T had significantly higher ($p<0.05$) cartilage SNR than all other sequences, while T2FS at 3T had the highest fluid SNR which was significantly higher ($p<0.05$) than all other sequences except FGRE at 3T (Figure 2). T2FS at 3T had significantly higher ($p<0.05$) CNR between cartilage and fluid and FGRE at 3T had significantly higher CNR between cartilage and bone than all other sequences (Figure 3). FGRE at 3T had the highest average sensitivity (0.42) and highest average accuracy (0.76) for detecting cartilage lesions while maintaining high specificity (average 0.89). FGRE at 3T also had the lowest interobserver variability (kappa 0.32) for determining the presence and absence of cartilage lesions (Table 1).

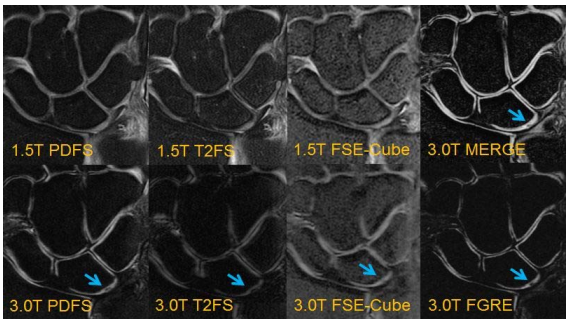

Figure 1: Representative images of the wrist demonstrating a cartilage lesion on the proximal lunate (blue arrows).

Sequence	Observer	Sensitivity	Specificity	Accuracy	Kappa
1.5T PDFS	1	0.24	0.88	0.70	0.11
	2	0.08	0.98	0.73	
1.5T T2FS	1	0.24	0.92	0.73	0.24
	2	0.04	0.97	0.71	
1.5T FSE-Cube	1	0.20	0.89	0.70	0.23
	2	0.04	0.98	0.72	
3.0T PDFS	1	0.32	0.88	0.72	0.12
	2	0.08	0.98	0.73	
3.0T T2FS	1	0.32	0.94	0.77	0.18
	2	0.04	0.98	0.72	
3.0T FSE-Cube	1	0.24	0.83	0.67	0.28
	2	0.16	0.98	0.76	
3.0T FGRE	1	0.60	0.83	0.77	0.32
	2	0.24	0.94	0.74	
3.0T MERGE	1	0.40	0.78	0.68	0.18
	2	0.16	0.88	0.68	

Table 1: Sensitivity, specificity, and accuracy of sequences by observer.

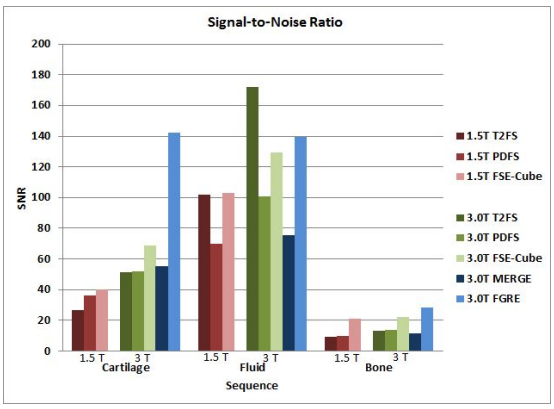

Figure 2: Signal-to noise-ratio of sequences.

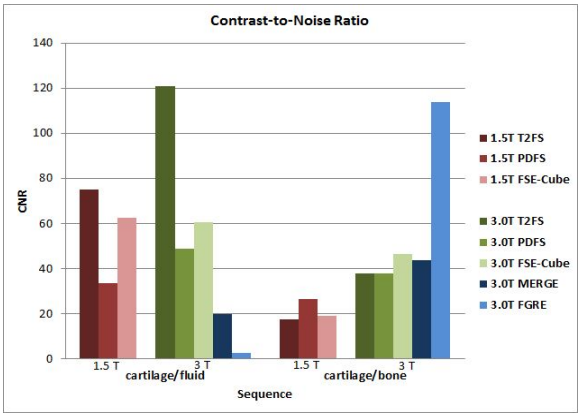

Figure 3: Contrast-to-noise ratio of sequences

Conclusion: MR sequences have higher cartilage and fluid SNR, higher contrast between cartilage and adjacent joint structures, and higher diagnostic performance for detecting cartilage lesion at 3T than at 1.5T. Diagnostic performance at 3T is higher for three-dimensional sequences than for two-dimensional sequences. FGRE at 3T was the best sequence for evaluating the articular cartilage of the wrist joint and had the highest cartilage SNR, highest CNR between cartilage and bone, highest subjective rank for image quality, and highest diagnostic performance for detecting cartilage lesions. However, despite improvements in cartilage assessment using high field strength scanners, multi-channel coils, and three-dimensional sequences, diagnostic performance for detecting cartilage lesions within the wrist joint remains low.