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FULL PAPER

Effect of traction on wrist joint space and cartilage visibility with and without MR arthrography

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Objective: To compare the effect of traction during non-arthrographic and arthrographic MR examination of the wrist with regard to joint space width, joint fluid dispersion and cartilage surface visibility.

Methods: Prospective 3-T MRI study of 100 wrists in 96 patients. The first 50 wrists underwent MR arthrography first without traction and then with traction. The following 50 wrists underwent standard MR first without traction and then with traction. On these examinations, two radiologists independently measured (i) joint space width, semi-quantitatively graded (ii) joint fluid dispersion between opposing cartilage surfaces and (iii) articular cartilage surface visibility. The three parameters were compared between the two groups.

Results: Traction led to an increase in joint space width at nearly all joints in all patients ($p < 0.05$), although more so

in the arthrography ($\Delta = 0.08$ – 0.79 mm, all $p < 0.05$) than in the non-arthrography ($\Delta = 0.001$ – 0.61 mm, all $p < 0.05$) group. Joint fluid dispersion and cartilage surface visibility improved after traction in nearly all joints ($p < 0.05$) in all patients and more so in the arthrographic than in the non-arthrography group.

Conclusion: Traction did significantly improve cartilage surface visibility for standard MRI of the wrist although the effect was not as great as that seen with MR arthrography or MR arthrography with traction.

Advances in knowledge: This is the first study to show the beneficial effect of traction during standard non-arthrography MRI of the wrist and compare the effect of traction between non-arthrographic and arthrographic MRI of the wrist.

INTRODUCTION

MR arthrography of the wrist with traction is a safe and well-tolerated technique known to increase visibility of cartilage surface defects, ligament tears and triangular fibrocartilage complex (TFCC) tears when compared with MR arthrography without traction.^{1–3} Traction involves applying a distraction force *via* a fixed weight to the limb under examination. Traction performed during MR arthrography distracts the wrist joint and separates opposing articular surfaces, allowing contrast to disperse more widely within the joint, which helps improve visibility of the articular cartilage surfaces.^{1–3} MR arthrography of the wrist with traction has an accuracy close to 100% for tears of the TFCC as well as the ulnotriquetral and scapholunate ligaments.³

The main limitation of MR arthrography is that it involves an intra-articular contrast injection which requires technical expertise, lengthens overall examination time, increases patient discomfort and has a minimal risk of infection. If a standard non-arthrographic MRI of the wrist

with traction could provide comparable information to MR arthrography or MR arthrography with traction, this would be of considerable benefit with regard to clinical applicability, efficiency and patient comfort. This study was designed to compare (a) wrist MRI without traction, (b) wrist MRI with traction, (c) MR arthrography without traction and (d) MR arthrography with traction with respect to the degree of joint space distraction, joint fluid dispersion and articular cartilage surface visibility.

METHODS AND MATERIALS

This was a prospective study approved by the local New territories east cluster-Prince of Wales Hospital (NTEC-PWH) Clinical Research Ethics Committee with signed informed consent from all patients.

Patients

100 consecutive wrists from 96 patients (53 males; 43 females; mean age: 40 years, range: 16–70 years) referred for MR wrist examination between November 2013 and November 2015 were studied. All patients had wrist pain

after trauma and were suspected to have by one of four orthopaedic surgeons (8–20 years of experience) either a TFCC or an intrinsic ligament injury. These 96 patients underwent one of two separate wrist MR examination protocols within 2 months of clinical assessment. The wrists of 48 consecutive patients (50 wrists) were assessed by (a) standard MR without traction, followed by (b) standard MR with traction. The wrists of another 48 consecutive patients (50 wrists) were assessed by (c) MR arthrography without traction, followed by (d) MR arthrography with traction. No patients were excluded in the study because they were unable to position the arm correctly.

MR examination of wrist

All MR examinations were performed on a 3.0-T MR whole-body system (Achieva™ TX-series; Philips Medical Systems, Best, Netherlands) using a commercially available dedicated eight-channel wrist coil array (SENSE wrist coil 8; Philips Medical Systems). Patients were examined prone with the wrist in pronation and the hand fully extended above the head, centred parallel to the long axis of the gantry. The wrist traction device was set up before MRI was performed (Figure 1a,b). Finger traps (ConMed Linvatec, Largo, FL) with all metal parts removed were applied to the index and ring fingers. MRI of the wrist was first acquired without traction and then with traction. MRI sequences, with and without traction, were performed as listed in Table 1. For traction studies, the finger traps were connected to a pre-selected weight (7 kg for males and 5 kg for females) using a non-elastic cord routed over the edge of the MR gantry by trained radiographers (Figure 1). The approximate time for standard MRI of the wrist was 16 min with an additional 2.5 min for traction sequences (Table 1). Excluding the time taken for injection (approximately 30 min), MR arthrography took approximately 23 min with an additional 2.5 min for traction sequences. Setting up the traction device and applying the finger traps took less than 5 min.

Wrist arthrography for the MR arthrography group

All patients underwent wrist arthrography followed immediately by MR arthrography. Three-compartmental intra-articular injection of a gadolinium-based contrast agent (gadoteric acid, Dotarem®; Guerbet, Roissy, France) was performed by one of two musculoskeletal radiologists (AWHN or RKLL) under fluoroscopic guidance using a dorsal approach. A 25-gauge needle was advanced into the radiocarpal joint between the radius and scaphoid, with confirmation of needle tip position by

a test injection of a trace of iodinated contrast (Omnipaque™ 300; GE Healthcare Ltd., Shanghai, China). Once the needle tip position was correctly confirmed, 3–5 ml of MR contrast medium (2 ml gadoteric acid in 200 ml normal saline) was injected into the radiocarpal joint under fluoroscopic control. If communication with the midcarpal or distal radioulnar joint was present, an additional 3–5 ml and 2–3 ml would be injected, respectively, totalling 8–13 ml. If no communication was present, the mid-carpal (interspace between the lunate, capitate and triquetrum bones) and the distal radioulnar joints were separately injected with 3–5 ml and 2–3 ml contrast solution, respectively.

MR image analysis

Three musculoskeletal radiologists (AWHN, RKLL and WKT), with 25, 9 and 3 years of musculoskeletal MR reporting experience, respectively, evaluated all four MR data sets [*i.e.* (a) standard MR without traction, (b) standard MR with traction, (c) MR arthrography without traction and (d) MR arthrography with traction] for joint space width and cartilage surface visibility. All measurements and grading were performed on a dedicated picture archiving and communication system workstation (Carestream solution working station v. 11.0; Carestream Health, Rochester, NY) following appropriate image digital zooming and contrast adjustment.

Joint space width

Two radiologists (RKLL and AWHN) measured the minimum joint space widths of the radioscapoid, radiolunate, ulnolunate, ulnotriquetral, scaphocapitate, lunocapitate, triquetrohamate, lunate-TFCC, TFCC-Lunotriquetral ligament (LTL) and radius-Scapholunate ligament (SLL) independently on intermediate-weighted coronal images before and after traction. Joint space widths, before and after traction, were measured separately in the same sitting. One of these two radiologists (RKLL) repeated the same joint space width measurements 2 weeks later. The minimum space width was defined as the shortest distance between opposing surfaces, *i.e.* either opposing articular cartilages surfaces or between articular cartilage and the TFCC articular disc/SLL/LTL or between the TFCC articular disc and the LTL. If an intrinsic ligament or TFCC articular disc was torn or a cartilage defect was present, the expected location of the ligament/articular disc/cartilage was estimated using the residual ligament/articular disc/cartilage as a landmark.^{1,2} Measurements to a 1/100th of a millimetre were recorded. For subsequent data analysis, the first joint space width reading by RKLL was used.

Figure 1. (a) Finger traps applied to the index and ring fingers (white arrows). (b) Finger traps are connected to a weight (white arrowhead) using a non-elastic cord (black arrow) routed through a simple in-house developed pulley system.

Table 1. MRI sequences of MR non-arthrography and arthrography before and after traction

MRI sequences	Plane	Slice thickness (mm)	TR (ms)	TE (ms)	Flip angle (°)	FOV (mm)	Matrix
MR non-arthrography before traction							
Fat-sat PD-W TSE	Axial	2.5	3985	30	90	80 × 77	320 × 218
UHR PD-W TSE	Coronal	1.5	3083	30	90	76 × 33	332 × 218
Fat-sat T2-W TSE	Coronal	1.5	3493	60	90	80 × 30	228 × 180
T1-W TSE	Coronal	1.5	665	9	90	80 × 33	268 × 228
Fat-sat T2-W TSE	Sagittal	1.5	4658	70	90	48 × 80	224 × 174
MR non-arthrography after traction							
UHR PD-W TSE	Coronal	1.5	3083	30	90	76 × 33	332 × 218
MR arthrography before traction							
Fat-sat T1-W TSE	Axial	2.5	678	19	90	80 × 80	228 × 182
Fat-sat T1-W TSE	Coronal	1.5	679	20	90	76 × 30	252 × 191
Fat-sat T1-W TSE	Sagittal	1.5	516	12	90	48 × 76	228 × 172
UHR PD-W TSE	Coronal	1.5	3083	30	90	76 × 33	332 × 218
Fat-sat PD-W TSE	Axial	2.5	3985	30	90	80 × 77	320 × 218
Fat-sat T2-W TSE	Sagittal	1.5	3740	70	90	48 × 80	224 × 174
MR non-arthrography after traction							
UHR PD-W TSE	Coronal	1.5	3083	30	90	76 × 33	332 × 218

Fat-sat, fat-saturated; FOV, field of view; PD-W, proton density-weighted; T1-W, T_1 weighted; T2-W, T_2 weighted; TE, time to echo; TR, time to repetition; TSE, turbo spin-echo; UHR, ultra-high resolution.

Fluid dispersion between opposing cartilage surfaces

Two radiologists (RKLL and WKT) independently graded the amount of contrast material in the radiosaphoid, radiolunate, scaphocapitate, lunocapitate and triquetrohamate spaces using a three-point scale: 0 = absent, with no joint fluid present between opposing cartilage surfaces on any sequential sagittal and coronal images; 1 = partial, with no joint fluid present between opposing cartilage surfaces on at least one sequential sagittal or coronal image; 2 = complete, with joint fluid present between opposing cartilage surfaces on all sequential sagittal or coronal images. One of these two radiologists (RKLL) repeated the same assessment 2 weeks later. For subsequent data analysis, the first reading of cartilage surface visibility by RKLL was used.

Articular cartilage surface visibility

Two radiologists (RKLL and WKT) semi-quantitatively graded the visibility of the articular cartilage surface in the radiosaphoid, radiolunate, scaphocapitate, lunocapitate and triquetrohamate spaces as good, intermediate and poor by consensus. "Good" visibility referred to a clear articular cartilage contour with an unambiguous outline, "poor" referred to non-visibility of the articular contour and "intermediate" referred to visible but ill-defined articular contour. The articular cartilage surface visibility at the radiosaphoid, radiolunate, scaphocapitate, lunocapitate and triquetrohamate articulations were independently assessed. One of these two radiologists (RKLL) repeated the same

assessment 2 weeks later. For subsequent data analysis, the first reading of cartilage surface visibility by RKLL was used.

Statistical analysis

All analyses were performed using SPSS® (IBM Corp., New York, NY; formerly SPSS Inc., Chicago, IL). All data sets were tested for normal distribution. The two-tailed paired t -test was used to compare mean joint space widths before and after traction for the non-arthrography and arthrography groups. The two-tailed non-paired t -test was used to compare the mean joint space widths between groups before and after traction. Intra- and interobserver agreement of joint space width was calculated using intraclass correlation coefficient with the following criteria applied to these agreements: $r > 0.8$ excellent, $r = 0.6$ – 0.8 good, $r = 0.4$ – 0.6 moderate, $r = 0.2$ – 0.4 fair and $r < 0.2$ poor. Differences in fluid dispersion and cartilage surface visibility before and after traction were calculated using the χ^2 test. Interobserver agreement for semi-quantitative analysis of cartilage visibility was assessed by Cohen's kappa coefficient, and results were interpreted according to the criteria proposed by Landis and Koch.⁴ For all tests, a probability p level of <0.05 was regarded as statistically significant.

RESULTS

There were no significant differences in age ($p = 0.56$), sex ($p = 0.42$) or laterality of the wrists ($p = 0.54$) between the non-arthrography and arthrography groups. No patient reported

Table 2. Mean joint space width (mm, $\pm$ standard deviation) before and after traction for both standard non-arthrography and arthrography MRI

Joints	Non-arthrography			Arthrography			$\Delta B-A$ (mm)	p -value	No traction		Traction	
	No traction (mm)	Traction (mm)	ΔA	p -value	no traction (mm)	traction (mm)	ΔB	p -value	Arthrogram–non-arthrogram (mm)	p -value	Arthrogram–non-arthrogram (mm)	p -value
Radioscaphoid	0.09 $\pm$ 0.15	0.28 $\pm$ 0.32	0.19	2.20 $\times 10^{-7}$	0.19 $\pm$ 0.24	1.04 $\pm$ 0.77	0.85	3.33 $\times 10^{-11}$	0.10	0.009	0.76	1.75 $\times 10^{-8}$
Radiolunate	0.02 $\pm$ 0.06	0.10 $\pm$ 0.25	0.08	0.019	0.06 $\pm$ 0.11	0.57 $\pm$ 0.62	0.51	1.63 $\times 10^{-7}$	0.04	0.029	0.47	6.17 $\times 10^{-6}$
Ulnolunate	1.22 $\pm$ 0.65	1.48 $\pm$ 0.63	0.26	3.23 $\times 10^{-4}$	1.67 $\pm$ 0.80	2.11 $\pm$ 1.02	0.44	1.55 $\times 10^{-4}$	0.45	0.003	0.63	3.68 $\times 10^{-4}$
Ulnotriquetral	3.56 $\pm$ 1.87	4.17 $\pm$ 1.68	0.61	1.28 $\times 10^{-3}$	3.99 $\pm$ 1.41	4.78 $\pm$ 1.76	0.79	2.40 $\times 10^{-4}$	0.43	0.200	0.61	0.082
IScaphocapitate	0.01 $\pm$ 0.06	0.16 $\pm$ 0.23	0.15	2.96 $\times 10^{-5}$	0.06 $\pm$ 0.13	0.39 $\pm$ 0.38	0.33	1.40 $\times 10^{-7}$	0.05	0.037	0.23	0.001
Lunocapitate	0.00 $\pm$ 0.00	0.14 $\pm$ 0.23	0.14	4.00 $\times 10^{-5}$	0.01 $\pm$ 0.07	0.45 $\pm$ 0.77	0.44	2.01 $\times 10^{-4}$	0.01	0.208	0.31	0.010
Triquetrohamate	0.006 $\pm$ 0.02	0.007 $\pm$ 0.03	0.001	0.798	0.006 $\pm$ 0.04	0.09 $\pm$ 0.25	0.084	0.017	0.00	0.949	0.083	0.018
Lunate-TFCC	0.01 $\pm$ 0.06	0.03 $\pm$ 0.09	0.02	0.057	0.10 $\pm$ 0.25	0.22 $\pm$ 0.34	0.12	0.001	0.09	0.012	0.19	3.47 $\times 10^{-4}$
TFCC-LT	0.03 $\pm$ 0.07	0.03 $\pm$ 0.08	0	0.684	0.15 $\pm$ 0.37	0.29 $\pm$ 0.49	0.14	0.008	0.12	0.023	0.26	4.97 $\times 10^{-4}$
Radius-SL space	0.06 $\pm$ 0.14	0.11 $\pm$ 0.28	0.05	0.047	0.22 $\pm$ 0.42	0.62 $\pm$ 0.69	0.4	2.77 $\times 10^{-6}$	0.16	0.013	0.51	7.63 $\times 10^{-6}$

LT, lunotriquetral ligament; SL, scapholunate ligament; TFCC, triangular fibrocartilage complex.

There was a significant increase in joint space width for nearly all joint spaces assessed (bolded). The scaphocapitate joint space showed the largest difference before and after traction.

Figure 2. Intermediate-weighted coronal MR non-arthrography without traction (a) and with traction (b). Before traction, cartilage surface visibility at the radioscaphoid, radiolunate and triquetrohamate joints (white arrows) was of “poor” grade, whereas cartilage surface visibility of the scaphocapitate and lunocapitate joints (black arrows) were of “intermediate” grade. The joint fluid filling of the scaphocapitate and radioscaphoid joints was “partial” (grade 1), whereas the joint fluid filling of the radiolunate, triquetrohamate and lunocapitate was “absent” (grade 0). After traction, the cartilage visibility of all except the triquetrohamate joints improved to “good”, and joint fluid filling of all, except for the triquetrohamate joint, improved to “complete” (grade 2). All joint space distances of the intercarpal joints, except for the triquetrohamate joint, increased after axial traction.

discomfort, pain or any other symptoms related to the traction immediately after the MR examination.

Joint space width

Prior to traction, overall joint space widths in the non-arthrography group were significantly less than that in the arthrography group, except at the ulnotriquetral, lunocapitate and triquetrohamate joint spaces (Table 2).

After traction, joint space widths increased in both groups although the degree of increase in joint space width was significantly less in

the non-arthrography group (mean 0.15 mm, range 0.001–0.61 mm, all $p < 0.05$) than in the arthrography group (mean 0.41 mm, range 0.08–0.79 mm, $p < 0.05$), except at the ulnolunate ($p = 0.16$) and ulnotriquetral ($p = 0.51$) joints (Table 2).

In other words, for the non-arthrography group, traction significantly increased most joint spaces (except for the triquetrohamate, lunate-TFCC and TFCC-LT spaces), whereas for the arthrography group, traction significantly increased all joint spaces (Table 2, Figures 2 and 3). Both the interobserver correlation (r : 0.61–0.74) and intraobserver

Figure 3. Intermediate-weighted coronal MR arthrography without traction (a) and with traction (b). Before traction, cartilage surface visibility at radioscaphoid, radiolunate, lunocapitate and triquetrohamate joints (white arrows) was “good”, whereas cartilage surface visibility of the scaphocapitate joint (black arrow) was “poor”. The joint fluid (contrast) filling between cartilages at the radioscaphoid joint was “complete” (grade 2), whereas the joint fluid (contrast) filling at the radiolunate, scaphocapitate, triquetrohamate and lunocapitate joints was “partial” (grade 1). After traction, cartilage visibility at the scaphocapitate joint (black arrows) improved to “good”, whereas joint fluid (contrast) filling of the lunocapitate, scaphocapitate, triquetrohamate joints improved to “complete” (grade 2). All joint space distances of the intercarpal joints increased after axial traction. When compared with non-MR arthrography, the increase in joint space widths was greater in the arthrography group than in the non-arthrography group. This is also a paradiagonal tear of the articular disc of the triangular fibrocartilage complex present.

correlation (r : 0.65–0.79) for measurement of joint space width were good.

Fluid dispersion and visibility of articular cartilage

In the non-arthrography group, traction improved both fluid dispersion and cartilage visibility for all joint spaces (all $p \leq 0.05$), except for the triquetrohamate joint space (Tables 3 and 4, Figures 2 and 3). In the arthrography group, traction improved both fluid dispersion and cartilage surface visibility for all joint spaces (all $p \leq 0.05$), except for the cartilage visibility at the radioscaphoid joint space (Tables 3 and 4). Both the interobserver correlation (k : 0.60–0.71) and intraobserver correlation (k : 0.71–0.79) for grading of joint fluid dispersion and cartilage surface visibility were good.

DISCUSSION

The main clinical indication for MRI of the wrist is to evaluate for the presence of TFCC, intrinsic ligament or articular cartilage injury.^{5–17} MR arthrography of the wrist with traction is known to significantly increase the detection of TFCC and intrinsic ligament injury, as well as improve articular cartilage surface visibility.^{2,3,18} This beneficial effect of traction is most likely due to joint space widening with increased dispersion of contrast medium between articular surfaces. During traction, all joint spaces are non-selectively distracted.^{1–3} Traction is easy to apply and is clinically well tolerated with no known complications.^{1–3,19} To date, all studies investigating the effects of traction on MR of the wrist have been performed on MR arthrography studies.^{1–3}

This study showed that traction led to a significant increase in nearly all joint spaces irrespective of whether or not the patient underwent arthrography. The degree of joint space widening that occurred with traction in patients without arthrography was not as great as that with arthrography. This was most likely due to arthrography lessening the vacuum effect between opposing joint surfaces.²⁰

Traction improved the visibility of nearly all articular cartilage surfaces. The improvement seen with traction in non-arthrography MR examinations was not as great as that seen with arthrography examinations, as contrast medium dispersion along the joint spaces has the added benefit of improving contrast differentiation between opposing cartilage surfaces. The most clinically relevant wrist joint spaces with respect to articular cartilage injury are the radioscaphoid and radiolunate joint spaces. For non-arthrography MRI examinations, cartilage visibility at these joint spaces were mainly graded “poor” to “intermediate” prior to traction and mainly graded “intermediate” to “good” after traction. For MR arthrography examinations, cartilage visibility at these joint spaces was mainly graded “good” prior to traction and almost invariably graded “good” after traction.

This study showed that traction performed during standard non-arthrography MRI examination of the wrist did, almost universally, increase joint space width and improve articular cartilage surface visibility, although this improvement was not as great as that seen with MR arthrography and particularly MR arthrography with

Table 3. Comparison of joint fluid dispersion between opposing cartilage surfaces at different joint spaces before and after traction in both standard non-arthrography and arthrography MRI

Joint fluid dispersion		Non-arthrography			Arthrography		
		No traction (number of cases)	Traction (number of cases)	<i>p</i> -value	No traction (number of cases)	Traction (number of cases)	<i>p</i> -value
Radioscaphoid	None	9	7	2.73×10^{-4}	4	1	1.33×10^{-2}
	Partial	36	20		23	6	
	Complete	6	24		23	43	
Radiolunate	No	34	27	2.16×10^{-2}	10	3	4.8×10^{-2}
	Partial	15	15		27	13	
	Complete	2	9		13	34	
Scaphocapitate	No	23	16	1.70×10^{-4}	15	7	1.33×10^{-4}
	Partial	25	17		23	5	
	Complete	3	18		12	38	
Lunocapitate	No	47	26	5.13×10^{-5}	11	3	3.4×10^{-5}
	Partial	4	7		28	8	
	Complete	0	18		11	39	
Triquetrohamate	No	36	27	0.058	9	2	1.3×10^{-4}
	Partial	13	19		29	11	
	Complete	2	5		12	37	

Traction improved joint fluid dispersion in all joint spaces ($p < 0.05$, bolded) except for the triquetrohamate joint space in the non-arthrography group.

Table 4. Comparison of cartilage surface visibility at different joint spaces before and after traction in both standard non-arthrography MRI and MR arthrography

Articular cartilage surface visibility		Non-arthrogram			Arthrogram		
		Without traction (number of cases)	With traction (number of cases)	<i>p</i> -value	Without traction (number of cases)	With traction (number of cases)	<i>p</i> -value
Radioscaphoid	Good	9	28	5.89×10^{-6}	37	44	1.33×10^{-1}
	Intermediate	24	15		6	3	
	Poor	18	8		7	3	
Radiolunate	Good	2	12	0.001	35	44	4.8×10^{-2}
	Intermediate	31	31		7	3	
	Poor	18	8		8	3	
Scaphocapitate	Good	3	20	2.50×10^{-5}	21	44	1.33×10^{-4}
	Intermediate	25	18		22	5	
	Poor	23	13		7	1	
Lunocapitate	Good	0	19	1.16×10^{-4}	17	42	3.4×10^{-5}
	Intermediate	19	18		23	5	
	Poor	32	14		1	3	
Triquetrohamate	Good	2	7	0.061	15	38	1.3×10^{-4}
	Intermediate	18	21		27	6	
	Poor	31	23		8	6	

Traction improved articular cartilage surface visibility of all joint spaces ($p < 0.05$, bolded), except at the triquetrohamate joint space in the non-arthrography group and the radioscaphoid joint space in the MR-arthrography group. The radioscaphoid cartilage in the MR arthrography group had good visibility even before traction, such that the improvement after traction did not reach statistical significance.

traction. Whether indirect MR arthrography followed by traction would show the same improvement had not been studied.

This study had some limitations. First, as the information acquired through MRI was deemed sufficient for clinical decision-making, few patients required subsequent wrist arthroscopy.²¹ Therefore, cartilage injury could not be evaluated in this study as there was no comparative standard available. The detection of cartilage injury would, nevertheless, be highly dependent on good articular cartilage surface visibility, and this was one of the main criteria assessed in this study. Second, it was not possible to blind readers as to whether the examination being assessed had been performed with or without traction, as the effect of traction was readily apparent by the degree of joint distraction present. Third, due to perceived patient compliance issues, the study was designed so that each patient either underwent a standard MRI followed by traction or a MR arthrography followed by traction, as opposed to a single

patient undergoing all four examinations in two settings. TFCC and intrinsic ligament injuries were not assessed, as such a study would ideally require arthroscopic correlation and very few patients in the current study cohort underwent arthroscopy.

In conclusion, traction performed during standard non-arthrography MR examination of the wrist significantly increases joint space width and improves articular cartilage surface visibility. The improvement in cartilage surface visibility is not as great as that seen with either MR arthrography or MR arthrography with traction.

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REFERENCES

- Gunter D, Becce F, Richarme D, Palhais NS, Meuli R, Theumann N. Direct magnetic resonance arthrography of the wrist with axial traction: a feasibility study to assess joint cartilage. *J Magn Reson Imaging* 2011; **34**: 239–44. doi: <https://doi.org/10.1002/jmri.22615>
- Cerny M, Marlois R, Theumann N, Bollmann C, Wehrli L, Richarme D, et al. 3-T direct MR arthrography of the wrist: value of

- finger trap distraction to assess intrinsic ligament and triangular fibrocartilage complex tears. *Eur J Radiol* 2013; **82**: e582–89.
3. Lee RK, Griffith JF, Ng AW, Nung RC, Yeung DK. Wrist traction during MR arthrography improves detection of triangular fibrocartilage complex and intrinsic ligament tears and visibility of articular cartilage. *AJR Am J Roentgenol* 2016; **206**: 155–61. doi: <https://doi.org/10.2214/AJR.15.14948>
 4. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics* 1977; **33**: 159–74. doi: <https://doi.org/10.2307/2529310>
 5. Magee T. Comparison of 3-T MRI and arthroscopy of intrinsic wrist ligament and TFCC tears. *AJR Am J Roentgenol* 2009; **192**: 80–5. doi: <https://doi.org/10.2214/AJR.08.1089>
 6. Lee YH, Choi YR, Kim S, Song HT, Suh JS. Intrinsic ligament and triangular fibrocartilage complex (TFCC) tears of the wrist: comparison of isovolumetric 3D-THRIVE sequence MR arthrography and conventional MR image at 3 T. *Magn Reson Imaging* 2013; **31**: 221–6. doi: <https://doi.org/10.1016/j.mri.2012.06.024>
 7. Lee RK, Ng AW, Tong CS, Griffith JF, Tse WL, Wong C, et al. Intrinsic ligament and triangular fibrocartilage complex tears of the wrist: comparison of MDCT arthrography, conventional 3-T MRI, and MR arthrography. *Skeletal Radiol* 2013; **42**: 1277–85. doi: <https://doi.org/10.1007/s00256-013-1666-8>
 8. Moser T, Dosch JC, Moussaoui A, Dietemann JL. Wrist ligament tears: evaluation of MRI and combined MDCT and MR arthrography. *AJR Am J Roentgenol* 2007; **188**: 1278–86. doi: <https://doi.org/10.2214/AJR.06.0288>
 9. Schmid MR, Schertler T, Pfirrmann CW, Saupe N, Manestar M, Wildermuth S, et al. Interosseous ligament tears of the wrist: comparison of multi-detector row CT arthrography and MR imaging. *Radiology* 2005; **237**: 1008–13. doi: <https://doi.org/10.1148/radiol.2373041450>
 10. Hayter CL, Gold SL, Potter HG. Magnetic resonance imaging of the wrist: bone and cartilage injury. *J Magn Reson Imaging* 2013; **37**: 1005–19. doi: <https://doi.org/10.1002/jmri.23845>
 11. Weber MA, von Stillfried F, Kloth JK, Rehnitz C. Cartilage imaging of the hand and wrist using 3-T MRI. *Semin Musculoskelet Radiol* 2012; **16**: 71–87. doi: <https://doi.org/10.1055/s-0032-1311759>
 12. Wang ZX, Chen SL, Wang QQ, Liu B, Zhu J, Shen J. The performance of magnetic resonance imaging in the detection of triangular fibrocartilage complex injury: a meta-analysis. *J Hand Surg Eur Vol* 2015; **40**: 477–84. doi: <https://doi.org/10.1177/1753193414567425>
 13. Ramnath RR. 3T MR imaging of the musculoskeletal system (part II): clinical applications. *Magn Reson Imaging Clin N Am* 2006; **14**: 41–62.
 14. Chhabra A, Soldatos T, Thawait GK, Del Grande F, Thakkar RS, Means KR Jr, et al. Current perspectives on the advantages of 3-T MR imaging of the wrist. *Radiographics* 2012; **32**: 879–96. doi: <https://doi.org/10.1148/rg.323115741>
 15. Zink JV, Souteyrand P, Guis S, Chagnaud C, Le Fur Y, Militianu D, et al. Standardized quantitative measurements of wrist cartilage in healthy humans using 3T magnetic resonance imaging. *World J Orthop* 2015; **6**: 641–48. doi: <https://doi.org/10.5312/wjo.v6.i8.641>
 16. Cody ME, Nakamura DT, Small KM, Yoshioka H. MR imaging of the triangular fibrocartilage complex. *Magn Reson Imaging Clin N Am* 2015; **23**: 393–403. doi: <https://doi.org/10.1016/j.mric.2015.04.001>
 17. Johnson D, Stevens KJ, Riley G, Shapiro L, Yoshioka H, Gold GE. Approach to MR imaging of the elbow and wrist: technical aspects and innovation. *Magn Reson Imaging Clin N Am* 2015; **23**: 355–66. doi: <https://doi.org/10.1016/j.mric.2015.04.008>
 18. Slutsky DJ. Current innovations in wrist arthroscopy. *J Hand Surg Am* 2012; **37**: 1932–41. doi: <https://doi.org/10.1016/j.jhsa.2012.06.028>
 19. Leventhal EL, Moore DC, Akelman E, Wolfe SW, Crisco JJ. Conformational changes in the carpus during finger trap distraction. *J Hand Surg Am* 2010; **35**: 237–44. doi: <https://doi.org/10.1016/j.jhsa.2009.11.013>
 20. Yanagawa Y, Ohsaka H, Jitsuike K, Yoshizawa T, Takeuchi I, Omori K, et al. Vacuum phenomenon. *Emerg Radiol* 2016; **23**: 377–82. doi: <https://doi.org/10.1007/s10140-016-1401-6>
 21. Obdeijn MC, Tuijthof GJ, van der Horst CM, Mathoulin C, Liverneaux P. Trends in wrist arthroscopy. *J Wrist Surg* 2013; **2**: 239–46. doi: <https://doi.org/10.1055/s-0033-1351355>