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Athletic injuries of the extensor carpi ulnaris subsheath: MRI findings and utility of gadolinium-enhanced fat-saturated T1-weighted sequences with wrist pronation and supination

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Abstract *Objective* To report the magnetic resonance imaging (MRI) findings in athletic injuries of the extensor carpi ulnaris (ECU) subsheath, assessing the utility of gadolinium-enhanced (Gd) fat-saturated (FS) T1-weighted sequences with wrist pronation and supination. *Methods* Sixteen patients (13 male, three female; mean age 30.3years) with athletic injuries of the ECU subsheath sustained between January 2003 and June 2009 were included in this retrospective study. Initial and follow-up 1.5-T wrist MRIs were performed with transverse T1-weighted and STIR sequences in pronation, and Gd FS T1-weighted sequences with wrist pronation and supination. Two radiologists assessed the type of injury (A to C), ECU tendon stability, associated lesions and rated pulse sequences using a three-point scale: 1=poor, 2=good and 3=excellent. *Results* Gd-enhanced FS T1-weighted transverse sequences in supination (2.63) and pronation (2.56) were most valuable, compared with STIR (2.19) and T1-weighted (1.94). Nine type A, one type B and six type C injuries were found. There were trends towards diminution in size, signal intensity and enhancement of associated pouches on follow-up MRI and tendon stabilisation within the ulnar groove. *Conclusion* Gd-enhanced FS T1-weighted sequences with wrist pronation and supination are most valuable in assessing and follow-up athletic injuries of the ECU subsheath on 1.5-T MRI.

Keywords Extensor carpi ulnaris · Tendon · Athletic injuries · Wrist · Magnetic resonance imaging

Introduction

The extensor carpi ulnaris (ECU) tendon lies in the sixth dorsal compartment of the wrist. At the level of the distal ulna, the tendon runs through a 15- to 20-mm-long fibro-osseous tunnel composed of the ECU subsheath and the ulnar groove (Fig. 1) [1, 2]. When the wrist is in supination, the ECU tendon is forced medially to an angle of approximately 30 degrees and is maintained in its compartment by its own subsheath [3]. Selective lesions of the subsheath led to tendon subluxation or dislocation in previous computed tomography (CT) and magnetic resonance imaging (MRI) studies on cadavers [4–6]. The extensor retinaculum overlies the ECU subsheath and plays no stabilising role with regard to the ECU tendon (Fig. 1) [2].

Athletic injuries of the ECU subsheath {the classification system is explained later in the text (Fig. 2) [9]} are rarely seen in clinical practice, due in part to the fact that these lesions are commonly misdiagnosed as wrist sprain [7]. They are mainly encountered in athletes playing racket or stick sports and happen during forceful supination of the forearm, combined with flexion and ulnar

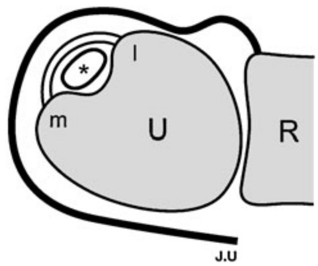

Fig. 1 Schematic representation of the ECU subsheath (*white stripe*) on the dorso-medial aspect of the distal ulna (*U*). The ECU tendon (*) lies in its fibro-osseous tunnel composed of the subsheath and the ulnar groove. The extensor retinaculum (*black stripe*) overlies the ECU subsheath and does not insert on the ulna (*R* radius, *n* medial attachment site, *l* lateral attachment site)

deviation of the wrist [3, 8, 9]. Clinical features consist of acute dorsal and ulnar-sided wrist pain, associated with a painful snapping or clicking sensation of the ECU tendon during the provocative test [7]. Confirmation of the injury at imaging may be challenging, especially as regards dynamic instability of the tendon [10–12].

There is little consensus regarding the treatment of those injuries [7]. A few authors proposed a conservative approach consisting of rest, non-steroidal anti-inflammatory drugs and splinting or casting of the wrist for 6–12 weeks [3, 4, 13, 14]. On the other hand, some authors reported small series of patients treated by direct repair of the tear or various reconstruction techniques [9, 11, 15–17].

Our study had two purposes. The first was to report the MRI findings in athletic injuries of the ECU subsheath. The second was to assess the utility of the transverse gadolinium (Gd) fat-saturated (FS) T1-weighted sequences with wrist pronation and supination in the evaluation and follow-up of those injuries.

Materials and methods

Institutional review board approved this retrospective study, with waiver of patient's informed consent for the review of all clinical data.

Study group

Twenty-one consecutive patients with clinical and MRI diagnoses of athletic injuries of the ECU subsheath were identified in a search of our institutional database. All the patients were referred between January 2003 and June 2009 by a sports medicine physician and a hand surgeon, both experienced in athletic injuries of the wrist and hand. Exclusion criteria were: (1) previous ulnar-sided wrist surgery (n=2), (2) MRI performed more than 3 months after the onset of injury (n=2), and (3) significant (motion) artefacts preventing accurate image analysis (n=1). Hence, 16 patients (13 male, three female; mean age 30.3 years, range 17-56) with wrist MRI (nine right, seven left) performed at an average of 1.5 months after trauma were included. Fourteen of these patients sustained their injury while playing tennis (among them, ten were professional players), one was playing golf and the last patient injured his wrist during a fall in a football match. Eight of those 16 patients underwent at least one follow-up MRI between 1 and 2 months after the initial study, while the other eight were lost to follow-up. All the patients were treated conservatively with prolonged immobilisation.

Control group

Thirty consecutive patients (19 female, 11 male; mean age 46.9 years, range 17-63) with wrist MRI (19 right, 11 left) performed between January 2009 and March 2009 were included as a control group. All these patients met the following criteria: (1) no ulnar-sided wrist pain, (2) no acute or subacute (≤4 weeks) wrist and hand trauma, (3) no previous ulnar-sided wrist pain, (4) no previous ulnar-sided wrist surgery, (5) no systemic inflammatory disease. Clinical histories were: carpal tunnel syndrome (n=16), radial-sided wrist pain (n=7), focal painful swelling of the wrist (n=6) and carpal bone tumour work-up (n=1).

MRI protocols

All MRI studies were performed on one of two 1.5-T units (Magnetom Avanto; Siemens Medical Solutions, Erlangen,

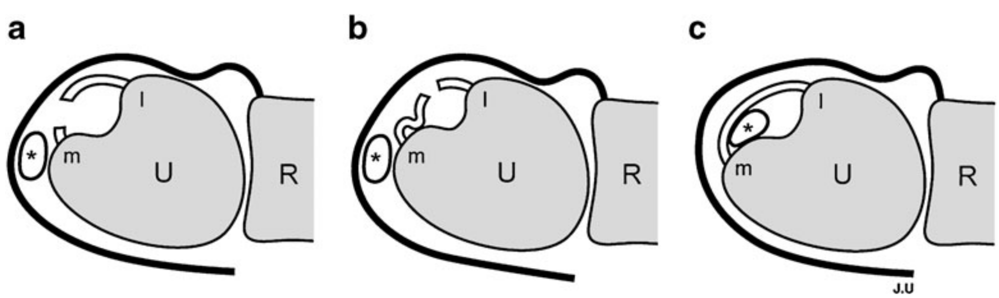

Fig. 2 Schematic representation of the type A (**a**), type B (**b**) and type C (**c**) injuries of the ECU subsheath (*white stripe*). **a** In type A injuries, the subsheath tears near its medial attachment site (*m*) on the ulna (*U* which may lead to ECU tendon (*) dislocation from the ulnar groove. **b** In type B injuries, the subsheath tears near its lateral attachment site (*l*) on the ulna which may also lead to ECU tendon dislocation. **c**) In type C injuries, the subsheath is stripped from the ulnar periosteum at its medial attachment site, creating a pouch in which the ECU tendon may subluxate

Table 1 Detailed parameters of the applied transverse pulse sequences (*NA* not applicable)

Parameter	T1-weighted fast spin-echo	STIR fast spin-echo	Gd-enhanced fat-saturated T1-weighted spin-echo
Repetition time (ms)	315-460	2,100-3,340	420-501
Echo time (ms)	12-14	25-58	12-15
Inversion time (msec)	N/A	140-150	NA
Field of view (mm)	60×60	70×70	60×60
Matrix	320×160-320	256×160-256	320×160-320
Number of signals acquired	3-4	3-4	3-4
Echo-train length	1	9	3
Section thickness (mm)	3.5	3.5	3.5
Gap (%)	10	40	10

Germany; or Signa Excite; GE Healthcare, Waukesha, Wis., USA). The patients were examined in the prone position, with the arm extended over the head and the wrist in pronation and placed in the centre of a two- or four-channel phased-array dedicated wrist coil. Imaging was obtained from the radial and ulnar distal metaphyses to the second row of carpal bones. The following three transverse pulse sequences were reviewed: (1) T1-weighted fast spin-echo, (2) short inversion time inversion-recovery (STIR) fast spin-echo and (3) Gd FS (Dotarem, 0.2 ml/kg; Guerbet, Villepinte, France) T1-weighted spin-echo. Furthermore, every patient in the study group benefited from an additional transverse Gd FS T1-weighted spin-echo sequence with the wrist in supination, performed immediately after the sequence in pronation and applying the same parameters. The parameters of the reviewed pulse sequences are detailed in Table 1. All other available sequences were not considered in this study.

MRI analysis

An experienced radiologist and a fellowship-trained radiologist (Observers 1 and 2, with 18 and 2 years' experience in musculoskeletal imaging, respectively) read all the images independently. In the case of disagreement, a consensus was reached with a third radiologist (Observer 3, with 7 years' experience in musculoskeletal imaging). Measurements, obtained to the nearest tenth of a millimetre, were performed at a picture archiving and communication system workstation (Kodak Carestream; Carestream Health, Rochester, N.Y., USA).

In the study group, the following features were assessed:

1. The type of ECU subsheath injury was determined according to the classification system proposed by Inoue and Tamura (Fig. 2) [9].

In type A or B injuries, the subsheath was considered torn when a clear-cut gap was seen between two portions of the subsheath, with a stump at the medial or lateral attachment site, respectively.

In all types of injuries, an associated pouch at the medial edge of the ulnar groove was noted when present and measured along its medio-lateral and antero-posterior axes on STIR and Gd FS T1-weighted images with wrist pronation and supination. The signal intensity and enhancement of the pouch were rated in a semi-quantitative manner: 0=no signal intensity or enhancement; 1=signal or enhancement less intense than in adjacent vessels; 2=pouch and adjacent vessels equally intense or enhanced.In types A or B injuries, the subsheath was considered torn when a clear-cut gap was seen between two portions of the subsheath, with a stump at respectively the medial or lateral attachment site.

2. The stability of the ECU tendon within the ulnar groove was evaluated, both in pronation and supination of the wrist. Subluxation or dislocation, measured on Gd FS T1-weighted images, was noted as the percentage of the tendon width that crossed a tangent line to the medial aspect of the ulnar groove (Fig. 3) and rated as: moderate≤50% of the tendon width; substantial=50-99%; complete=100%.
3. The presence of the following associated lesions was also determined: ulnar head oedema, extensor

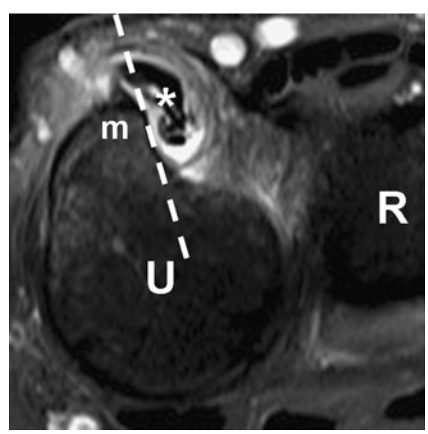

Fig. 3 Transverse Gd-enhanced FS T1-weighted spin-echo MR image (420/12) with wrist supination in a 26-year-old male patient reveals moderate subluxation (<50% of the tendon width) of the ECU tendon (*). Tendon stability is assessed semi-quantitatively as the percentage of the tendon width that crosses a tangent line (*white dotted line*) to the medial aspect of the ulnar groove (*R* radius, *U* ulna, *m* medial attachment site)

Table 2 MRI findings in athletic injuries of the ECU subsheath (*F* female, *M* male, *L* left, *R* right)

Patient	Gender	Age	Wrist	Time after injury (months)	Type of ECU subsheath injury[a]	Stump thickness (mm)	Pouch		ECU tendon stability[c]		Ulnar head oedema	Extensor retinaculum injury	ECU tenosynovitis	ECU tendinosis
							Present	Enhancement[b]	Pronation	Supination				
1	M	20	L	1	A	1.1	Yes	2	0	1	Yes	No	Yes	Yes
2	F	17	R	3	A	0.8	Yes	1	0	1	Yes	No	Yes	Yes
3	M	40	R	3	B		No	0	0	1	No	No	Yes	Yes
4	F	18	R	3	A	0.9	Yes	2	0	1	Yes	No	Yes	Yes
5	M	31	L	0	C		Yes	2	0	0	No	No	Yes	Yes
6	M	28	R	0	A	1.4	Yes	2	0	0	Yes	No	Yes	Yes
7	M	21	L	0	A	1.3	Yes	1	0	1	No	No	Yes	Yes
8	F	21	L	0	A	0.9	Yes	2	0	1	Yes	No	Yes	Yes
9	M	43	R	2	C		Yes	2	0	2	Yes	No	Yes	Yes
10	M	32	L	0	C		Yes	2	0	1	No	No	Yes	Yes
11	M	22	L	0	A	1.3	Yes	1	0	3	No	No	Yes	No
12	M	19	L	3	C		Yes	2	0	1	Yes	No	Yes	No
13	M	26	R	3	C		Yes	2	0	1	No	No	Yes	Yes
14	M	56	R	0	A	1.4	Yes	0	0	1	Yes	No	Yes	Yes
15	M	44	R	3	C		Yes	2	0	0	Yes	No	Yes	No
16	M	47	R	3	A	1.2	Yes	1	0	1	Yes	No	Yes	Yes

[a] Type of ECU subsheath injury: *A* medial tear, *B* lateral tear, *C* medial stripping of the ECU subsheath without a tear

[b] Pouch enhancement: *0* none, *1* less than adjacent vessels, *2* equal to adjacent vessels

[c] ECU tendon stability: *0* stable, *1* moderate subluxation (<50% tendon width), *2* substantial subluxation (50-99%), *3* complete dislocation

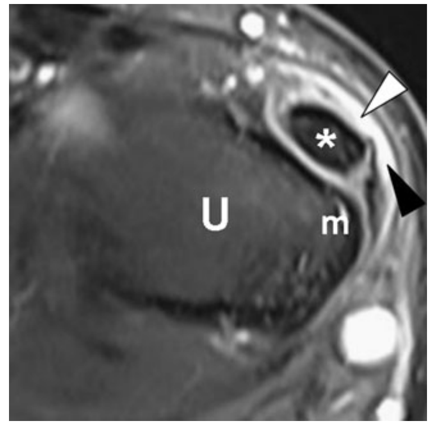

Fig. 4 Transverse Gd-enhanced FS T1-weighted spin-echo MR image (501/15) with wrist pronation in a 22-year-old male patient with a type A injury of the ECU subsheath (*white arrowhead*). The subsheath is torn near its medial attachment site (*m*) and a contrast- enhanced associated pouch (*black arrowhead*) is noted (*U* ulna, *ECU tendon)

retinaculum injury, tendinosis and tenosynovitis of the ECU.

4. Finally, the value of each of the four transverse pulse sequences was rated using a three-point scale: 0=poor, when the diagnosis of ECU subsheath injury was questionable at imaging; 1=good, when imaging was suggestive; 2=excellent, when the diagnosis was unequivocal.

In the control group, the following items were evaluated:

1. The visibility of each of the three portions (medial, central and lateral) of the ECU subsheath was

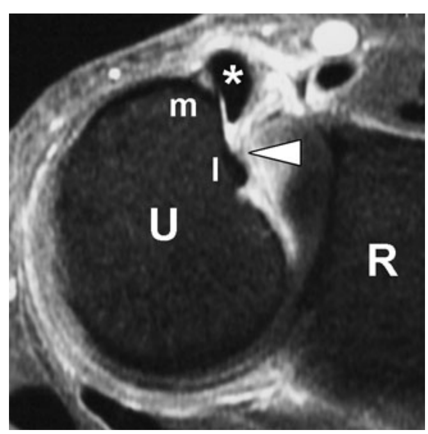

Fig. 5 Transverse Gadolinium-enhanced fat-saturated T1-weighted spin-echo MR image (420/12) with wrist supination in a 40-year-old male patient with a type B injury of the ECU subsheath (*white arrowhead*). The subsheath is torn near its lateral attachment site (l) and the stump has collapsed within the ulnar groove (*R* radius, *U* ulna, *m* medial attachment site, * ECU tendon)

Fig. 6 Transverse Gd-enhanced FS T1-weighted spin-echo MR image (501/15) with wrist supination in a 32-year-old male patient with a type C injury of the ECU subsheath. The subsheath is stripped at its medial attachment site and forms a contrast-enhanced pouch (*white arrowhead*) in which the ECU tendon (*) moderately (<50% of the tendon width) subluxates (*U* ulna, *l* lateral attachment site)

determined in the three transverse pulse sequences. Each portion was defined as visible when seen on at least one transverse image. When visible, the subsheath's thickness was measured near its medial attachment site on T1-weighted images.

Statistical analysis

All the data were processed using a statistical software package (R 2.7.0; R Foundation for Statistical Computing, Vienna, Austria). The differences in the ratings of the pulse sequences were tested by using the Wilcoxon rank sum test, with the Bonferroni correction to compensate for multiple comparisons. *P* values less than 0.05 were considered statistically significant. Inter-observer agreement for the value of the MRI pulse sequences was evaluated using Cohen's Kappa coefficient [18], and the results were interpreted according to the criteria proposed by Landis and Koch [19].

Results

Study group

Table 2 summarises the MRI findings in the 16 patients with athletic injuries of the ECU subsheath. We found nine (56.3%) type A (Fig. 4), one (6.3%) type B (Fig. 5) and six (37.5%) type C (Fig. 6) injuries. An associated pouch was always present in type A and C injuries. There was a trend towards diminution in size, signal intensity and enhancement of the pouch in the eight patients with

Table 3 Evolution of the MRI findings in follow-up studies (*ML* mediolateral, *AP* anteroposterior, *NA* not applicable)

Patient	Type of ECU subsheath injury[a]	Time of follow-up (months)	Pouch								ECU tendon stability[c]	
			STIR			Gd FS T1						
						Pronation		Supination			Pronation	Supination
			ML (mm)	AP (mm)	Signal intensity[b]	ML (mm)	AP (mm)	ML (mm)	AP (mm)	Enhancement		
1	A	NA	2.2	9.4	1	2	9.2	2.3	10.4	2	0	1
1	A	2	1.2	5.1	1	1.6	5.6	1	6.1	1	0	0
2	A	NA	1.2	3.8	1	1.8	4.1	2.5	2.9	1	0	1
2	A	3	0	0	0	0	0	0.7	2.8	1	0	1
5	C	NA	2.7	13	2	2.3	10.5	4.2	8.8	2	0	0
5	C	1	0	0	0	2.2	10.7	3.6	7.5	2	0	0
5	C	2	0	0	0	0	0	0	0	0	0	0
6	A	NA	0	0	0	1.9	13.8	1.6	11.2	2	0	0
6	A	2	0.7	4.6	0	2	11.3	1.6	10.5	2	0	0
6	A	4	0.6	3.9	0	1.6	5.8	1.8	6.4	2	0	0
8	A	NA	4.4	15.7	2	4.2	15	3.2	15.8	2	0	1
8	A	2	2.3	6.4	2	3.7	7.1	2.9	10.8	1	0	1
11	A	NA	2.7	19.8	2	4	20.2	4.2	16.6	1	0	3
11	A	2	1.2	8.5	0	2.5	7.6	3.3	13	1	0	2
11	A	3	3.1	12.4	1	3.4	12.1	4.8	17.3	2	0	2
11	A	4	1.8	4	0	2.3	7.2	3	7.4	1	0	2
11	A	5	1.5	3.6	0	1.9	5.8	2.1	5.5	1	0	1
12	C	NA	2	7.3	1	2.1	7.4	3.7	13.9	2	0	1
12	C	2	0	0	0	1.8	4.9	3.5	5.2	1	0	1
12	C	5	0	0	0	0	0	0	0	0	0	0
14	A	NA	1.8	8.2	1	2	8.3	2.3	8.6	1	0	1
14	A	6	0	0	0	0	0	0	0	0	0	1

[a] Type of ECU subsheath injury: A=medial tear, B=lateral tear, C=medial stripping of ECU subsheath without tear

[b] Pouch signal intensity/enhancement: *0* none, *1* less than adjacent vessels, *2* equal to adjacent vessels

[c] ECU tendon stability: *0* stable, *1* moderate subluxation (<50% tendon width), *2* substantial subluxation (50-99%), *3* complete dislocation

Table 4 Diagnostic value of the four transverse pulse sequences, with the corresponding kappa coefficient reflecting inter-observer agreement

Pulse sequence	Observer 1			Observer 2			Concordance	Kappa	Consensus		
	1	2	3	1	2	3			1	2	3
T1-weighted	3	12	1	0	14	2	0.75	0.26 (fair)	2	13	1
STIR	1	10	5	2	9	5	0.69	0.42 (moderate)	1	11	4
Gd-enhanced FS T1-weighted with wrist pronation	0	6	10	0	7	9	0.81	0.61 (substantial)	0	7	9
Gd-enhanced FS T1-weighted with wrist supination	0	6	10	0	6	10	0.88	0.73 (substantial)	0	6	10

follow-up MRI (Table 3), except in one tennis player (Patient 11) who had a relapse of their injury at 3 months, with a concomitant increase in size, signal intensity and enhancement of the pouch. We noted a slightly faster decline in the pouch's signal intensity on STIR, compared with Gd FS T1-weighted images. In the nine patients with type A injuries, the mean stump thickness was 1.1 mm (range 0.8-1.4).

No ECU tendon was subluxated or dislocated in wrist pronation. In supination, there were 11 moderate and one substantial subluxations, and one complete dislocation. We noticed a trend towards tendon stabilisation within the ulnar groove on follow-up MRI (Table 3).

Ulnar head oedema was present in ten (62.5%) patients. We found no extensor retinaculum injury. All the 16 patients presented ECU tenosynovitis, while 13 (81.3%) had tendinosis.

Table 4 displays the results of the ratings of the four transverse pulse sequences, with the corresponding Kappa coefficient. Overall, the Gd FS T1-weighted transverse sequences in supination (2.63) and pronation (2.56) were the most valuable, compared with STIR (2.19) and T1-weighted (1.94) sequences. The difference between the two Gd FS and the T1-weighted sequences was statistically significant (p=0.01), but the difference between the contrast-enhanced sequences and the STIR was not (p = 0.06), although a definite trend was noted. Inter-observer agreement was substantial for both Gd FS T1-weighted images with wrist supination and pronation (0.73 and 0.61 respectively), moderate for STIR (0.42) and fair for T1-weighted images (0.26).

Control group

The visibility of each portion of the ECU subsheath in the 30 control patients is reported in Table 5. The medial portion was the most visible, in 66.7 (20/30) to 80% (24/30) of the cases. The lateral portion was the least visible, in only 30 (9/30) to 50% (15/30) of the cases. Overall, 70% (63/90) of the portions of the subsheath were seen on at least one transverse sequence.

In the 22 (73.3%) cases where the medial portion was visible on T1-weighted images, the mean subsheath thickness was 0.3 mm (range 0.3-0.4).

Discussion

Our results demonstrate that the Gd FS T1-weighted sequences with wrist pronation and supination are the most valuable for assessing athletic injuries of the ECU subsheath, compared with T1-weighted (p=0.01) or STIR (p = 0.06). The results were slightly better with wrist supination (2.63) than in pronation (2.56), probably because the subsheath was stressed in supination [3–6], with exposition of some non-displaced tearing. We think that the "stress test" in supination of the wrist is more useful in better displaying the subsheath's tear and its associated pouch than in assessing the acute instability of the ECU tendon. Indeed, the clinical significance of the tendon subluxation or dislocation is questionable, as recently reported by Lee et al. [12] in an ultrasound study in asymptomatic volunteers. However, these authors applied the measurement system proposed by Pratt et al. [10] to evaluate tendon instability, which is more sensitive than the one we used in this study but also associated with a higher rate of false-positives. According to our results, one of the interests of evaluating ECU tendon stability with wrist supination lies in the follow-up, as there was a trend towards tendon stabilisation within the ulnar groove after immobilisation.

Besides, we think that GD chelate administration is mandatory when assessing ECU subsheath injuries, especially as we noticed a faster decline in the pouch's signal intensity on STIR than on Gd FS T1-weighted images. In cases where only STIR or T2-weighted images were performed, this later finding may lead to premature

Table 5 Visibility of the three portions of the ECU subsheath in the 30 patients of the control group

	Medial	Central	Lateral	Total
T1-weighted	22/30 (73.3%)	24/30 (80%)	10/30 (33.3%)	56/90 (62.2%)
STIR	24/30 (80%)	21/30 (70%)	15/30 (50%)	60/90 (66.7%)
Gd-enhanced FS T1-weighted with wrist pronation	20/30 (66.7%)	19/30 (63.3%)	9/30 (30%)	48/90 (53.3%)
Total	66/90 (73.3%)	64/90 (71.1%)	34/90 (37.8%)	

discontinuation of the treatment with return to sports activity and relapse of the injury.

Type B injuries were the least frequent (6.3%) in our study, which is concordant with previously published studies [9, 11]. However, we found a higher percentage of type A (56.3%) than type C (37.5%) injuries than in a recent series with surgical correlation [11]. This result could be explained by the fact that, in our study, all the wrists were examined relatively shortly after the injury (mean 1.5 months), while they were examined later in other studies [9, 11]. The delay between injury and imaging may have enabled partial or complete healing of the tear. Anyway, the most important MRI finding is the presence of an associated pouch in all injuries of the medial portion of the subsheath, whether type A or C.

The results in the control group demonstrate that non-visibility of a portion of the subsheath is not a reliable sign for diagnosing the injury, especially on its lateral portion where it was visible in only 37.8% of the control patients overall.

We acknowledge the following limitations of our study. First, its retrospective nature. Second, we have no surgical correlation to assert the presence of ECU subsheath injury. However, all the patients were referred by physicians with great experience in sports injuries of the wrist and hand, and at least one follow-up imaging study was obtained in half of the patients.

In conclusion, athletic injuries of the ECU subsheath are visible on 1.5-T wrist MRI. Gadolinium-enhanced FS T1-weighted sequences with wrist pronation and supination are the most valuable for assessing and following up these lesions.

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