Journal of Orthopaedic Science xxx (2018) 1–6

Contents lists available at ScienceDirect

Journal of Orthopaedic Science

journal homepage: http://www.elsevier.com/locate/jos

Original Article

Magnetic resonance imaging analysis of the extensor carpi ulnaris tendon and distal radioulnar joint in triangular fibrocartilage complex tears

Shigeru Santo [a], Shohei Omokawa [b, *], Akio Iida [c], Takamasa Shimizu [c], Hideo Hasegawa [c], Yasuhito Tanaka [c]

[a] *Department of Orthopedic Surgery, Osaka Gyomeikan Hospital, Osaka, Japan*
[b] *Department of Hand Surgery, Nara Medical University, Kashihara, Japan*
[c] *Department of Orthopedic Surgery, Nara Medical University, Kashihara, Japan*

A R T I C L E I N F O

Article history:
Received 1 June 2017
Received in revised form
21 March 2018
Accepted 16 May 2018
Available online xxx

A B S T R A C T

Background: We compared the incidence of extensor carpi ulnaris (ECU) tendon and distal radioulnar joint (DRUJ) abnormalities using magnetic resonance imaging (MRI) between patients with triangular fibrocartilage complex (TFCC) tears and subjects without ulnar wrist pain. Additionally, we aimed to identify potential predictors of these MRI lesions.

Methods: The TFCC group comprised 70 consecutive patients with TFCC tears. The control group comprised 70 age- and sex-matched subjects without ulnar wrist pain. We evaluated the presence or absence of fluid collection in the DRUJ and ECU peritendinous area and longitudinal ECU tendon splitting. Dimensions of the fluid collection area around the ECU tendon were measured to evaluate the severity. The incidences of these abnormal MRI findings were compared between the two groups. We analyzed the correlation between the presence of ECU tendon and DRUJ lesions and variables including age, magnitude of ulnar variance, and type of TFCC tear.

Results: Significant differences were found between the two groups in the incidence of fluid collection of the DRUJ and ECU peritendinous area, and longitudinal ECU tendon splitting. Among the 70 patients with TFCC tears, age and the magnitude of ulnar variance were significantly correlated with the severity of fluid collection around the ECU tendon. The magnitude of ulnar variance in patients with DRUJ fluid collection was significantly larger than that in patients without fluid collection. There was a significant correlation between the presence of disc tears and DRUJ fluid collection.

Conclusion: We found a higher incidence of accompanying abnormal MRI findings of the ECU tendon and DRUJ in patients with TFCC tears than in the control group. The presence of disc tears, the magnitude of ulnar variance, and age may be risk factors for these MRI lesions associated with TFCC tears.

1. Introduction

Determining the cause of ulnar-sided wrist pain is difficult because of the anatomical complexity, overlap of anatomical structures, and biomechanical properties of this aspect of the wrist [1]. Despite recent technological advances in imaging modalities, hand surgeons often find it difficult to distinguish intra-articular lesions, such as triangular fibrocartilage complex (TFCC) tears and ulnocarpal abutment syndrome, from extra-articular pathologies of the extensor carpi ulnaris (ECU) tendon, such as tendinopathy or tenosynovitis [2]. Kakar and Garcia-Elias [3] proposed the “Four-Leaf Clover” algorithm to differentiate among various types of distal radioulnar joint (DRUJ) dysfunction, which may be caused by a variety of pathologies with multifactorial etiologies. They indicated that it is important to evaluate four pathological states, namely TFCC injury, bone deformity, cartilage damage, and ECU tendon instability, and that these conditions may overlap one another.

A previous study of surgically treated ECU tendon lesions showed that 39% of patients had TFCC tears or degeneration, and the authors concluded that isolated ECU tendon lesions were rare

* Corresponding author. Department of Hand Surgery, Nara Medical University, 840 Shijyo-cho Kashihara, Nara, 634-8522, Japan.
E-mail address: omokawa@gaia.eonet.ne.jp (S. Omokawa).

https://doi.org/10.1016/j.jos.2018.05.009

[4]. Additionally, the published literature contains a case report of complete ECU tendon rupture associated with TFCC injury [5]. Thus, information is lacking regarding the frequency of ECU tendon disorders in patients with TFCC tears. Moreover, no data are currently available on risk factors associated with the prevalence of ECU tendon and DRUJ disorders associated with TFCC injury.

We hypothesized that ECU tendon and DRUJ abnormalities are highly associated with TFCC tears and that aging, the magnitude of positive ulnar variance, and an extended duration of symptoms are predisposing factors. Therefore, we used magnetic resonance imaging (MRI) to investigate the incidence of abnormal findings of the ECU tendon and DRUJ in patients with TFCC tears and patients without known ulnar wrist problems. Furthermore, we sought to identify potential predictors of these lesions.

2. Methods

From 2006 to 2013, we enrolled 596 consecutive patients who underwent wrist MRI with a microscopy coil (1.5-T Philips Achieva; Philips Medical Systems, Best, the Netherlands) because of persistent wrist pain or a soft tissue mass on the wrist of unknown etiology (Fig. 1). We excluded 22 patients with rheumatoid arthritis, 93 patients with acute injury, and 14 patients aged $\leq$15 years. Among the remaining 467 patients, 208 patients had ulnar wrist pain and 259 patients had no ulnar-side wrist problems. The institutional review board of the hospital approved the study design. All patients provided informed consent to participate in this study.

2.1. Selection of the TFCC tear group

We included 70 consecutive patients with TFCC injury from the 208 patients with ulnar wrist pain, and preoperative MRI findings were used for the present analysis (Table 1). A TFCC tear was diagnosed according to positive physical examination and MRI findings. The positive MRI finding of a TFCC tear was high intensity at the fovea or disc on coronal T2-weighted images. We confirmed the diagnosis of a TFCC foveal or disc tear with arthroscopic evaluation in 64 (91%) patients, and tears in 6 (9%) patients were confirmed by open surgery. Based on the intraoperative findings, we identified 40 radioulnar ligament tears at the ulnar fovea, 47 articular disc tears, and 17 concomitant tears.

2.2. Control group selection

The control group comprised 70 patients from the 259 patients without ulnar wrist pain. These patients were age- and sex-

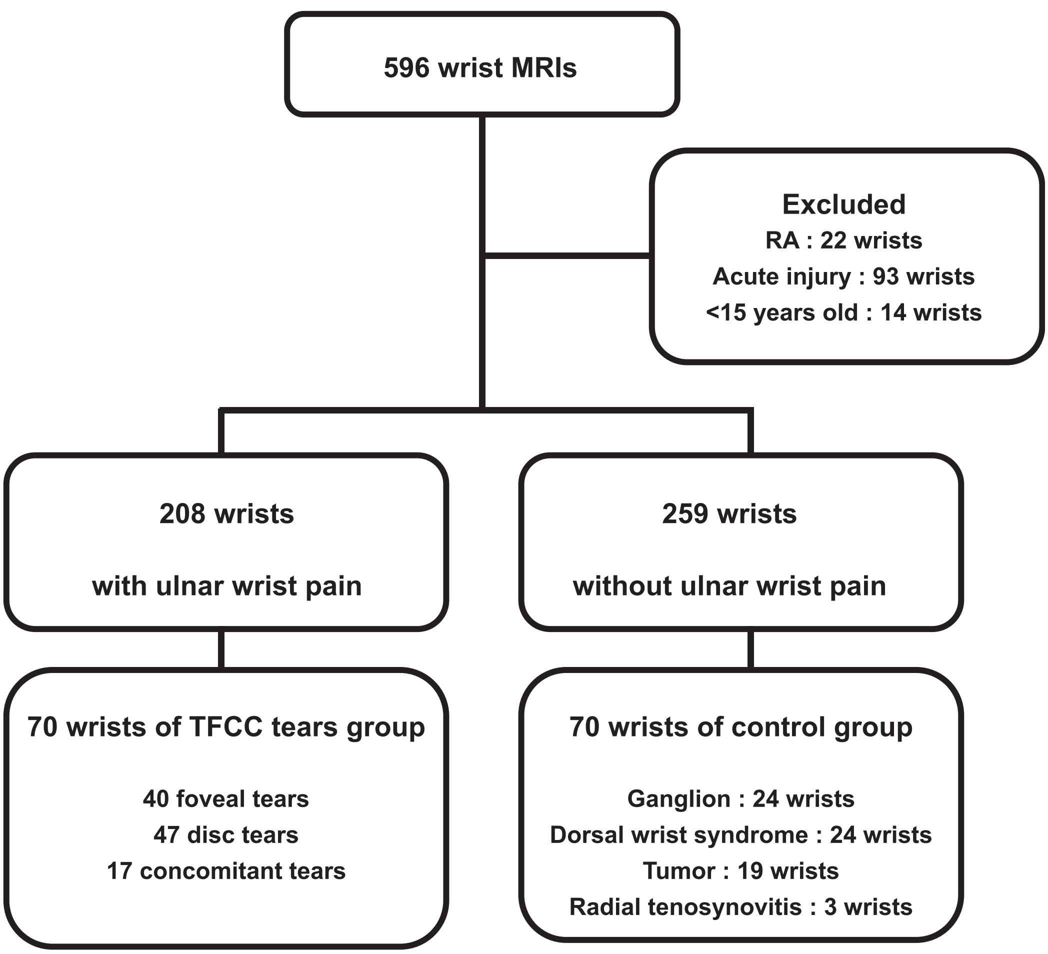

Fig. 1. Flow chart depicting the selection process and number of wrists among the patients with TFCC tears and controls. MRI: magnetic resonance imaging; TFCC: triangular fibrocartilage complex; RA: rheumatoid arthritis.

Table 1
Demographic characteristics of patients in the TFCC tear and control groups.

	TFCC tears n = 70	Control n = 70
Sex		
Female, n	48	48
Male, n	22	22
Age, years	41 (16–77)	42 (16–73)
UV, mm	0.6	−0.7
Duration, months	11 (1–90)	
Surgical procedure		
Ligament repair	37	
Arthroscopic debridement	7	
USO	20	
Ligament repair and USO	3	
Arthroscopic wafer procedure	1	
Darrach procedure	1	
HIA	1	

Data are presented as n or mean (range). TFCC: triangular fibrocartilage complex, UV: ulnar variance, HIA: hemiresection interposition arthroplasty, USO: ulnar shortening osteotomy.

matched with patients in the TFCC tear group (Table 1). The wrist MRI findings of these patients were also used for analysis.

2.3. MRI analysis

We evaluated the ECU tendon and DRUJ abnormalities based on axial and coronal MRI scans. Abnormal MRI findings included peritendinous fluid collection and longitudinal splitting of the ECU tendon and DRUJ fluid collection. These lesions were represented by high-intensity areas on T2-weighted images (Fig. 2). We measured the dimension of the high-intensity area around the ECU tendon and the width of the DRUJ lesion on T2-weighted images. We evaluated the severity and presence or absence of peritendinous fluid collection in three regions: the ECU tendon groove of the ulna, ulna styloid process, and distal extensor retinaculum. The maximum values of the dimensions in the three regions were used for statistical analysis. The presence or absence of peritendinous fluid collection was identified by a cut-off value, which was determined by a value greater than 2 standard deviations above the mean of the control group. The presence of DRUJ fluid collection was defined as an intra-articular high-intensity area of >1 mm in width on axial or coronal images. We also observed the location of the longitudinal split of the ECU tendon in the three regions to investigate which area was affected by ECU tendinopathy.

2.4. Statistical analysis

We evaluated differences in the incidence of associated abnormal MRI findings of the ECU tendon and DRUJ between patients with TFCC tears and the control group using the chi–square test. The severity of fluid collection of the ECU tendon was compared between the two groups using Student's *t*-test. We compared the frequency of the location of the longitudinal split of the ECU tendon between the two groups in each area (ECU tendon groove, styloid process, and distal extensor retinaculum) using the chi–square test. We performed univariate analysis to identify factors correlated with ECU tendon and DRUJ lesions in the 70 patients with TFCC tears. We analyzed the following factors: patient age and sex, symptom duration, magnitude of ulnar variance on a posteroanterior simple radiograph, and injury characteristics such as the presence of foveal and disc tears. A p value of <0.05 was considered statistically significant.

3. Results

Significant differences were found in the dimensions of fluid collection around the ECU tendon between the TFCC tear group (mean ± standard deviation, 18.1 ± 6.7 mm^2) and control group (6.6 ± 4.5 mm^2) ($p = 0.000$). Among the 70 patients with TFCC tears, 41 (59%) wrists had ECU tendon fluid collection, 29 (41%) had DRUJ fluid collection, and 36 (51%) had longitudinal ECU tendon splitting based on the current MRI observations. Among the 70 patients in the control group, 4 (6%) wrists had ECU tendon fluid collection, 14 (20%) had longitudinal ECU tendon splitting, and 9 (13%) had DRUJ fluid collection. The incidence of these ECU tendon and DRUJ abnormalities in the TFCC tear group was significantly higher than that in the control group ($p < 0.01$).

Among the 70 patients with TFCC tears, age and the magnitude of ulnar variance were significantly correlated with the severity of ECU tendon fluid collection (age: $r = 0.28$, $p < 0.05$; ulnar variance: $r = 0.44$, $p < 0.05$). The symptom duration had no significant correlation with the severity of peritendinous fluid collection. There was no significant difference between the presence or absence of disc tears and foveal tears in the ECU tendon lesions on MRI. The magnitude of ulnar variance with DRUJ fluid collection

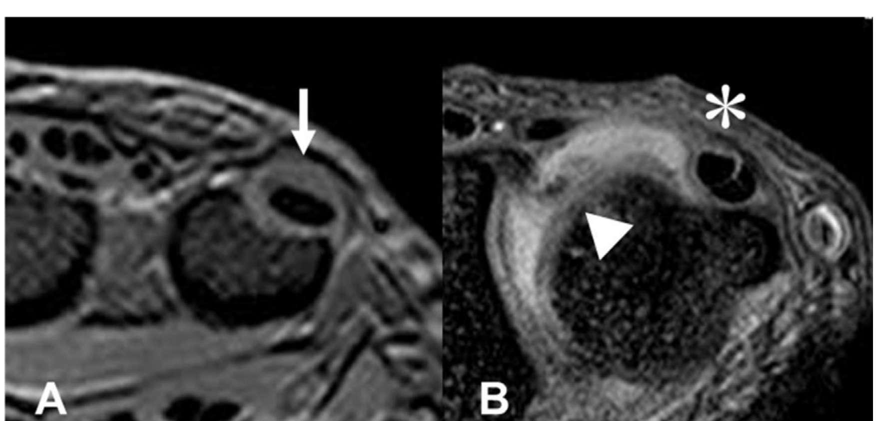

Fig. 2. Magnetic resonance images showing abnormal findings of the ECU tendon and DRUJ. **a** Fluid collection around the ECU tendon was considered to be present when a peritendinous high-intensity area was observed on axial T2-weighted images (white arrow). **b** Fluid collection in the DRUJ was considered to be present when an intra-articular high-intensity area was observed on axial T2-weighted images (white arrowhead). Longitudinal splitting of the ECU tendon was observed as a splitting high-intensity area within the ECU tendon on axial T2-weighted images (asterisk). ECU: extensor carpi ulnaris; DRUJ: distal radioulnar joint.

Please cite this article in press as: Santo S, et al., Magnetic resonance imaging analysis of the extensor carpi ulnaris tendon and distal radioulnar joint in triangular fibrocartilage complex tears, Journal of Orthopaedic Science (2018), https://doi.org/10.1016/j.jos.2018.05.009

was significantly larger than that without fluid collection ($p < 0.05$). The presence of a disc tear was significantly correlated with the presence of DRUJ fluid collection ($p < 0.05$). Fluid collection in the DRUJ tended to affect older patients ($p = 0.09$) (Tables 2 and 3).

In the TFCC tear group, the longitudinal splitting of the ECU tendon was found in 14% at the groove, 16% at the styloid process, and 44% at the extensor retinaculum. In the control group, the longitudinal ECU splitting was found in 1% at the groove, 1% at the styloid process, and 20% at the extensor retinaculum (Table 4). In each location, the incidence of a split in the TFCC tear group was significantly higher than that in the control group. With respect to the location of the longitudinal split of the ECU tendon, the frequency of a split was higher in the distal retinaculum region in both groups.

4. Discussion

The current MRI analysis showed that the frequency of ECU tendon abnormalities was significantly higher in patients with TFCC tears than in patients without ulnar wrist problems. We interpreted fluid collection and longitudinal splitting of the ECU tendon as pathological conditions of ECU tenosynovitis and tendinopathy. The present results indicate that considerable overlap exists between pathologies of the ECU tendon and TFCC and that concurrent manifestation of these pathologies is frequent in patients with ulnar wrist problems. The TFCC and ECU tendon are in close anatomical proximity and have related functions at the ulnar aspect of the wrist. The floor of the ECU tendon is part of the TFCC. Furthermore, the TFCC is the primary stabilizer and the ECU tendon is the secondary stabilizer of the DRUJ [6,7]. In a cadaveric biomechanical study, the TFCC was identified as an important component of the pulley system for the ECU tendon, and the excursion and moment arm of the ECU tendon were significantly increased by releasing the ulnar attachment of the TFCC [8]. Because excessive dorsopalmar movements of the ulnar head increase the magnitude of the ECU tendon excursion during wrist motion, friction tendinopathy of the ECU tendon may occur clinically after a patient develops a TFCC ligament tear. Although the current analysis did not reveal a correlation between TFCC foveal tears with DRUJ instability and the severity of ECU tenosynovitis, a similar overlapping pathology between joint instability and surrounding tendon problems is observed in patients with chronic lateral ankle instability and peroneal tendon disorders because the peroneal tendon is the dynamic stabilizer of the ankle joint [9,10].

Patients with positive ulnar variance may have ulnocarpal abutment syndrome, which is more likely to be associated with articular disc tears of the TFCC and may lead to DRUJ and ulnocarpal arthritis. In the present study, the incidence of DRUJ abnormalities on MRI was higher in the TFCC tear population than in the control group. Moreover, the presence of DRUJ fluid collection was significantly correlated with the magnitude of positive ulnar variance and the presence of articular disc tears. Joint fluid collection may indicate an arthritic condition of the DRUJ. Because the articular disc of the TFCC provides a smooth gliding surface between the ulnar head and the ulnar carpus [6], loss of integrity in the fibrocartilage complex (disc tear) may contribute to DRUJ arthritis. A possible underlying mechanism of DRUJ arthritis is associated with concentration of stress in the disc compartment [11–13] and accumulation of chondral debris by repetitive pronosupination motions. Presence of chronic DRUJ incongruity with positive ulnar variance may also contribute to the arthritic condition of the DRUJ. Katayama et al. [14] investigated 1128 wrist radiographs to identify the distribution of primary osteoarthritis in the ulnar aspect of the wrist and analyzed the factors correlated with ulnar wrist osteoarthritis. They found that positive ulnar variance was the most significant factor correlated with osteoarthritis in the DRUJ.

We found that positive ulnar variance was also significantly correlated with the severity of fluid-positive ECU tenosynovitis in patients with TFCC tears. Chang et al. [15] investigated ECU

Table 4
Distribution of the location of ECU tendon longitudinal split.

	Total, n	Location		
		Groove	Styloid process	Retinaculum
TFCC tears (n = 70)	36[a]	10[a]	11[a]	31[a]
Control (n = 70)	14[a]	1[a]	1[a]	14[a]

ECU: extensor carpi ulnaris, TFCC: triangular fibrocartilage complex.
[a] $p < 0.01$.

Table 2
Predictors of abnormal findings of DRUJ and ECU tendon.

	Fluid collection in the DRUJ		Longitudinal ECU split		Severity of fluid collection around the ECU tendon
	(−)	(+)	(−)	(+)	
UV, mm	0.1 ± 1.4[a]	1.3 ± 2.9[a]	0.5 ± 1.7	0.6 ± 2.6	r = 0.44[a]
Age, years	39 ± 13	45 ± 16	40 ± 15	43 ± 14	r = 0.28[a]

Data are presented as mean ± standard deviation.
DRUJ: distal radioulnar joint, ECU: extensor carpi ulnaris, UV: ulnar variance.
[a] Indicates a significant difference ($p < 0.05$).

Table 3
Relationship of TFCC disc tears to accompanying abnormal findings of DRUJ and ECU tendon.

		Fluid collection in the DRUJ, n		Longitudinal ECU split, n		Severity of fluid collection around the ECU tendon, mm
		(−)	(+)	(−)	(+)	
Disc tear	(−)	18[a]	5[a]	11	12	16.8 ± 5.92
	(+)	23[a]	24[a]	23	24	18.8 ± 6.95

Data are presented as mean ± standard deviation.
TFCC: triangular fibrocartilage complex, DRUJ: distal radioulnar joint, ECU: extensor carpi ulnaris.
[a] The presence of a disc tear was significantly correlated with the presence of fluid collection in the DRUJ ($p < 0.05$).

Please cite this article in press as: Santo S, et al., Magnetic resonance imaging analysis of the extensor carpi ulnaris tendon and distal radioulnar joint in triangular fibrocartilage complex tears, Journal of Orthopaedic Science (2018), https://doi.org/10.1016/j.jos.2018.05.009

tendon pathology using wrist MRI and its association with distal ulnar morphology. They found a significant correlation among negative ulnar variance, ECU tendon subluxation, and tendinopathy. They also found that patients with ECU tendon subluxation had a shallower ECU tendon groove. Although the results of the current analysis are opposite those described by Chang et al. [15], any morphologic change in ulnar variance may affect the ECU tendon kinetics, leading to pathologic changes of the ECU tendon.

Increasing age had a weak correlation with the severity of fluid-positive ECU tenosynovitis and DRUJ arthritis. Some previous studies have shown a spontaneous increase in the incidence of positive ulnar variance with age [16,17]. This correlation may support the trend observed in the present study regarding the presence of DRUJ arthritis and increasing age. The changes associated with increasing age also result in a decline in the structure and function of human tendons [18], and previous studies have shown that age is a risk factor for upper extremity tendonitis and tenosynovitis [19,20]. Based on previous and the present results, we thus consider that the etiology of ECU tendinopathy is multifactorial and may be a result of both distal ulnar morphology and surrounding soft tissue problems. Furthermore, various intrinsic and extrinsic predisposing factors may contribute to the ECU tendon pathophysiology in patients with ECU tendinopathy in the clinical setting.

The ECU tendon runs in the sixth extensor compartment and is stabilized in the ulnar groove by a subsheath located inferior to the extensor retinaculum [21]. The sixth compartment is the second most common site of stenosing tenosynovitis at the wrist [22]. Although ECU tenosynovitis can be successfully treated by steroid injections, information is lacking regarding the exact location of ECU tendinopathy [23–27]. In the present study, longitudinal splitting of the ECU tendon in the control group occurred mostly in the extensor retinaculum area (20%) distal to the ulnar styloid, while the tendinopathy extended proximally in the ulnar styloid and subsheath area in patients with TFCC tears (52%). Although normal variation of the ECU tendon may manifest as longitudinal tendon splitting [28–30], the increased incidence of tendon abnormalities in the control group indicates that degenerative changes of the ECU tendon are inherent to the ECU tendon. These changes are associated with tendon angulation and compression during specific wrist and forearm positions. In forearm supination, the ECU tendon angulates at 30° immediately distal to the subsheath, and the angle and strain of the tendon are further increased with wrist flexion and ulnar deviation [31]. Thus, the ECU tendon may be irritated by repetitive stress motions of the forearm and wrist, leading to friction tendinopathy. Longitudinal splitting of the ECU tendon in patients with TFCC tears was observed not only in the distal retinaculum but also in the ulnar groove and styloid process. We consider that TFCC tears may contribute to the longitudinal extension of ECU tendinopathy because a TFCC disc tear may potentially increase the pressure in the ECU tenosynovial area, leading to swelling of the tendon and extension of the tendinopathy.

This study had several limitations. First, the clinical significance of the abnormal MRI findings of the ECU tendon is not clear because we did not explore the ECU tendon surgically, and the physical findings of the ECU tendon are unknown. Second, the control patients in the present study did not have completely normal wrists. Although these patients did not have ulnar wrist symptoms, they might have had unknown ulnar wrist pathologies compared with normal populations. Nevertheless, the incidence of tenosynovitis of the extensor tendons and DRUJ fluid collection on wrist MRI in asymptomatic patients was 4.3% and 12.5% in previous studies, respectively [32,33], which are comparable with the present results. Third, we consider that the reliability of the MRI interpretation is a limitation. Although we strictly defined the presence or absence of abnormal MRI findings of the DRUJ and ECU tendon, repeated interpretations by multiple observers are needed to increase the inter- and intra-observer reliability. Fourth, we did not collect data on postoperative MRI scans in patients who underwent surgery for TFCC tears. Thus, we could not evaluate whether these ECU tendon and DRUJ lesions on MRI were directly caused by TFCC injury. Future longitudinal MRI studies should clarify this question by analyzing the postoperative changes in patients with these pathologies.

In the present study, we found a higher incidence of accompanying abnormal MRI findings of the ECU tendon and DRUJ in patients with TFCC tears than in patients without known ulnar wrist pathologies. The presence of a TFCC disc tear and the magnitude of ulnar variance were found to be risk factors for DRUJ and ECU tendon lesions. The overlap of these two pathologies may contribute to the difficulty in identifying the cause of ulnar wrist pain.

Conflict of interest

The authors declare that they have no conflict of interest.

References

[1] Sachar K. Ulnar-sided wrist pain: evaluation and treatment of triangular fibrocartilage complex tears, ulnocarpal impaction syndrome, and lunotriquetral ligament tears. J Hand Surg Am 2012 Jul;37(7):1489–500.
[2] Ruland RT, Hogan CJ. The ECU synergy test: an aid to diagnose ECU tendonitis. J Hand Surg Am. 2008 Dec;33(10):1777–82.
[3] Kakar S, Garcia-Elias M. The "Four-Leaf Clover" treatment algorithm: a practical approach to manage disorders of the distal radioulnar joint. J Hand Surg Am. 2016 Apr;41(4):551–64.
[4] Allende C, Le Viet D. Extensor carpi ulnaris problems at the wrist - classification, surgical treatment and results. J Hand Surg Br 2005 Jun;30(3):265–72.
[5] Moran S, Ruby LK. Nonrheumatoid closed rupture of extensor carpi ulnaris tendon. J Hand Surg Am 1992 Mar;17(2):281–3.
[6] Palmer AK, Werner FW. The triangular fibrocartilage complex of the wrist—anatomy and function. J Hand Surg Am 1981 Mar;6(2):153–62.
[7] Spinner M, Kaplan EB. Extensor carpi ulnaris: its relationship to the stability of the distal radio-ulnar joint. Clin Orthop Relat Res 1970 Jan-Feb;68: 124–9.
[8] Tang JB, Ryu J, Kish V. The triangular fibrocartilage complex: an important component of the pulley for the ulnar wrist extensor. J Hand Surg Am 1998 Nov;23(6):986–91.
[9] DIGiovanni BF, Fraga CJ, Cohen BE, Shereff MJ. Associated injuries found in chronic lateral ankle instability. Foot Ankle Int 2000 Oct;21(10):809–15.
[10] Sammarco GJ, DiRaimondo CV. Chronic peroneus brevis tendon lesions. Foot Ankle 1989 Feb;9(4):163–70.
[11] Palmer AK, Werner FW. Biomechanics of the distal radioulnar joint. Clin Orthop Relat Res 1984 Jul-Aug;187:26–35.
[12] Palmer AK, Glisson RR, Werner FW. Relationship between ulnar variance and triangular fibrocartilage complex thickness. J Hand Surg Am 1984 Sep;9(5): 681–2.
[13] Sugimoto H, Shinozaki T, Ohsawa T. Triangular fibrocartilage in asymptomatic subjects: investigation of abnormal MR signal intensity. Radiology 1994 Apr;191(1):193–7.
[14] Katayama T, Ono H, Suzuki D, Akahane M, Omokawa S, Tanaka Y. Distribution of primary osteoarthritis in the ulnar aspect of the wrist and the factors that are correlated with ulnar wrist osteoarthritis: a cross-sectional study. Skeletal Radiol 2013 Sep;42(9):1253–8.
[15] Chang CY, Huang AJ, Bredella MA, Kattapuram SV, Torriani M. Association between distal ulnar morphology and extensor carpi ulnaris tendon pathology. Skeletal Radiol 2014 Jun;43(6):793–800.
[16] Metz VM, Schratter M, Dock WI, Grabenwöger F, Kuzbari R, Lang S, et al. Age-associated changes of the triangular fibrocartilage of the wrist: evaluation of the diagnostic performance of MR imaging. Radiology 1992 Jul;184(1): 217–20.
[17] Mimic ZD. Age changes in the triangular fibrocartilage of the wrist joint. J Anat 1978 Jun;126(Pt 2):367–84.
[18] Kannus P, Paavola M, Józsa L. Aging and degeneration of tendons. In: Maffulli N, Renstrom P, Leadbetter W, editors. Tendon injuries: basic science and clinical medicine. London: Springer; 2005. p. 25–31.
[19] Werner RA, Franzblau A, Gell N, Ulin SS, Armstrong TJ. A longitudinal study of industrial and clerical workers: predictors of upper extremity tendonitis. J Occup Rehabil 2005 Mar;15(1):37–46.

Please cite this article in press as: Santo S, et al., Magnetic resonance imaging analysis of the extensor carpi ulnaris tendon and distal radioulnar joint in triangular fibrocartilage complex tears, Journal of Orthopaedic Science (2018), https://doi.org/10.1016/j.jos.2018.05.009

[20] Wolf JM, Sturdivant RX, Owens BD. Incidence of de Quervain's tenosynovitis in a young, active population. J Hand Surg Am 2009 Jan;34(1):112–5.
[21] Palmer AK, Skahen JR, Werner FW, Glisson RR. The extensor retinaculum of the wrist: an anatomical and biomechanical study. J Hand Surg Br 1985 Feb;10(1):11–6.
[22] Wood MB, Dobyns JH. Sports-related extraarticular wrist syndromes. Clin Orthop Relat Res 1986 Jan;202:93–102.
[23] Futami T, Itoman M. Extensor carpi ulnaris syndrome. Acta Orthop Scand 1995 Dec;66(6):538–9.
[24] Hajj AA, Wood MB. Stenosing tenosynovitis of the extensor carpi ulnaris. J Hand Surg Am 1986 Jul;11(4):519–20.
[25] Kip PC, Peimer CA. Release of the sixth dorsal compartment. J Hand Surg Am 1994 Jul;19(4):599–601.
[26] Kurosawa K. Diagnostic value of extensor carpi ulnaris tenography for ulnar side wrist pain. J Jpn Soc Surg Hand 2006;23(6):912–7 [in Japanese].
[27] Nachinocar UG, Khanolkar KB. Stenosing tenovaginitis of extensor carpi ulnaris: brief report. J Bone Joint Surg Br 1988 Nov;70(5):842.
[28] Pınar Y, Gövsa F, Bilge O, Celik S. Accessory tendon slip arising from the extensor carpi ulnaris and its importance for wrist pain. Acta Orthop Traumatol Turcica 2012;46(2):132–5.
[29] Nakashima T. An accessory extensor digiti minimi arising from extensor carpi ulnaris. J Anat 1993 Feb;182(Pt 1):109–12.
[30] Mestdagh H, Bailleul JP, Vilette B, Bocquet F, Depreux R. Organization of the extensor complex of the digits. Anat Clin 1985;7(1):49–53.
[31] Kataoka T, Moritomo H, Omori S, Iida A, Omokawa S, Suzuki D, et al. Pressure and tendon strain in the sixth extensor compartment of the wrist during simulated provocative maneuvers for diagnosing extensor carpi ulnaris tendinitis. J Orthop Sci 2015 Nov;20(6):993–8.
[32] Couzens G, Daunt N, Crawford R, Ross M. Positive magnetic resonance imaging findings in the asymptomatic wrist. ANZ J Surg 2014 Jul-Aug;84(7–8):528–32.
[33] Parodi M, Silvestri E, Garlaschi G, Cimmino MA. How normal are the hands of normal controls? A study with dedicated magnetic resonance imaging. Clin Exp Rheumatol 2006 Mar-Apr;24(2):134–41.

Please cite this article in press as: Santo S, et al., Magnetic resonance imaging analysis of the extensor carpi ulnaris tendon and distal radioulnar joint in triangular fibrocartilage complex tears, Journal of Orthopaedic Science (2018), https://doi.org/10.1016/j.jos.2018.05.009