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Ulnar-sided wrist pain in the athlete (TFCC/DRUJ/ECU)

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Abstract
Purpose of review The goal of this manuscript is to review key historic and recent literature regarding extensor carpi ulnaris (ECU), triangular fibrocartilage complex (TFCC) and distal radioulnar joint (DRUJ) injuries, particularly in athletes.
Recent findings Many recent studies examining the ECU focus on clinical and radiographic diagnosis. Several physical exam findings are described in addition to the use of MRI and US. Imaging studies must be clinically correlated due to high incidence of findings in asymptomatic patients.

In regard to the TFCC/DRUJ, there are numerous recent studies that support the use of MRA as an adjunctive diagnostic study. There are also a number of repair constructs that are described for the various different kinds of TFCC pathology reviewed here.
Summary In summary, there are a number of options for the diagnosis and treatment of ulnar-sided wrist pain. Patient factors, especially in the athletic population, must be taken into account when approaching any patient with these pathologies.

Keywords Athlete · DRUJ · ECU · TFCC · Ulnar wrist pain

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Introduction

Injuries to the extensor carpi ulnaris (ECU), triangular fibrocartilage complex (TFCC), and distal radioulnar joint (DRUJ) are common diagnoses in athletes complaining of ulnar-sided wrist pain [1–8]. Sports requiring repeated pronation/supination, radial/ulnar deviation, and axial loading of the forearm and wrist predispose these athletes to ulnar-sided wrist pathology. ECU, DRUJ, and TFCC injuries are reported in athletes participating in golf, football, tennis, baseball, rugby, hockey, and basketball players [1–8]. These injuries are a common source of ulnar-sided wrist pain in an athletic population and may result in missed time from sport [2, 6, 7]. Early diagnosis and treatment is critical in this population in order to minimize time away from sport.

ECU

Anatomy

The extensor carpi ulnaris originates from the lateral epicondyle and inserts on the base of the fifth metacarpal. At the level of the wrist, the ECU tendon passes through the sixth dorsal extensor compartment within the ECU groove on the dorsal aspect of the ulna. The ECU tendon is held within its groove by the extensor retinaculum and its own separate subsheath in the distal 1.5–2 cm of the ulna [9]. A recent cadaveric study suggests that the proximal half of this subsheath has a greater contribution than the distal half in providing dynamic stabilization of the ECU in its groove [10•]. Additionally, the ulnar wall of the sixth compartment which houses the ECU tendon is composed of transverse fibers that extend proximally becoming confluent with the epimysium of the ECU muscle. These fibers are referred to as the linea jugata [11].

The function of the ECU depends on the position of the wrist. In supination, the tendon lies dorsal to the center of rotation of the wrist thus contributing more to extension in this position. Conversely, in pronation, the tendon lies more palmar and ulnar diminishing its contribution to extension [12]. Furthermore, rotation of the wrist affects the angle at which the ECU tendon exits the subsheath coursing towards its insertion point. In supination, the tendon exits at approximately 30° compared to a pronated position in which the tendon exits in a more longitudinal direction [3, 5, 9]. Therefore, it is believed that tension on the subsheath is greatest during activities involving supination and holding the wrist is a flexed and/or ulnarly deviated position.

Distal ulnar morphology may also play a role in the development of ECU pathology. In a recent study reviewing MRI findings of patients with ECU pathology and/or subluxation, negative ulnar variance was associated with the presence of ECU pathology and instability. The depth of the ulnar groove was also evaluated and shallow grooves trended towards significant ECU pathology [13•]. Additionally, a large ulnar styloid may also contribute to development of tendinopathy via a direct mechanical irritation of the tendon [14].

Classification

In 2006, Montalvan et al. reported on 28 tennis players with ulnar-sided wrist pain stemming from pathology of the ECU. These patients were classified broadly into three groups—instability, tendinopathy, and tendon rupture. Clinically, it is useful to group ECU-related injuries in this way as it helps to guide treatment [5].

Innoue and Tamura previously classified patients with instability in a report of 12 patients with recurrent ECU dislocations. All patients underwent surgical exploration and repair or reconstruction of the ECU subsheath. The authors noted three types of ECU sheath disruptions (ulnar disruption, radial disruption, or periosteal avulsion of the ECU subsheath) [15, 16].

Subsequently, Allende et al. reported classification system based on a series of 28 surgically treated wrists. Their system classifies sheath lesions and lesions of the tendon itself [17].

Diagnosis

Clinical examination

The clinical examination is very helpful in differentiating the etiology of ulnar-sided wrist pain. In the case of unstable ECU tendons, there is typically an acute event that is noted by the patient. Conversely, patients with stable ECU tendons who have tendinopathy will more likely present with vague dorsal ulnar wrist pain with a history of a more insidious onset.

On physical examination, patients with instability may present with a spectrum of symptoms. In some cases, dislocation of the tendon is reproducible and may be painful or painless. Passive motion may not place enough tension on the tendon to reproduce symptoms and active examination should be undertaken. Pain with resisted extension and ulnar deviation may be indicative of tendinopathy or tenosynovitis as well. Pressure within the sixth extensor compartment is highest when the wrist and forearm are supinated and patients with tendinopathy will experience pain in this position [18•]. Lastly, weakness in the absence of pain may indicate rupture of the ECU tendon.

The ECU synergy test is a described maneuver proposed to help differentiate ECU pathology from other intrarticular diagnoses. The test is performed with the patients arm resting on the table and elbow flexed to 90° with the wrist in supination. The patient is asked to radially abduct the thumb against resistance. Reproduction of pain in the ECU is a positive test. The test is based on the theory that there is isometric activation of the ECU during resisted thumb abduction [19].

More recently, the "ice cream scoop" test has been proposed. This test is performed with the patient's wrist in pronation, ulnar deviation, and extension. The examiner palpates the ECU tendon and has the patient proceed with a scooping motion. Any subluxation of the tendon is noted as a positive exam finding [20].

Imaging

Magnetic resonance imaging

Magnetic resonance imaging may be useful in the diagnosis of ECU pathology. Tenosynovitis and tendinopathy will manifest as areas of increased signal intensity, although areas of altered signal intensity may also be found in normal tendon as well [5]. One recent study reports a sensitivity of 57% and specificity of 88% [21••]. The integrity of other critical structures including the extensor retinaculum and ECU subsheath may be evaluated using MRI as well, but may not be consistently seen in all exams. Knowing the position of the ECU tendon is highly dependent on the position of the wrist, examinations should be taken in both pronation and supination [22]. Last, while MRI may be valuable in identifying ECU pathology, the entire wrist is concomitantly evaluated with these studies allowing for diagnosis of other possible causes of symptoms as well.

Ultrasound

Ultrasound has emerged as an alternative imaging study in the diagnosis of suspected ECU pathology. Generally easily accessible, ultrasound examination may be performed in pronation/supination, allows for contralateral comparison, and may assess inflammatory changes. Dynamic evaluation in different positions may be useful in diagnosis and is easily performed with ultrasound [23]. Of note, previous ultrasound examination studies in healthy volunteers demonstrate up to 50% volar displacement of the ECU tendon in maximum supination, ulnar deviation, and flexion of the wrist and may be a normal finding [24, 25]. Furthermore, up to 75% of asymptomatic wrists may demonstrate tendinosis or tearing on ultrasound [26••]. Therefore, it is important to correlate imaging with clinical findings.

Treatment

Tendinosis of the ECU is typically treated non-surgically. Rest, activity modification, and a period of immobilization will often resolve symptoms. This is followed by progressive rehabilitation protocols in order for athletes to return to their normal activities.

In more chronic cases, or cases that do not respond to conservative management, surgical intervention may be called for. Division of the tendon in the affected area and debridement of necrotic tissue diminishes tendon size and may help alleviate symptoms. Surgical exploration also allows for evaluation of any extraneous septa between the ECU and extensor digiti minimi which may be released [17]. Release of the division between the fifth and sixth extensor compartments should also be considered to help decompress the sixth compartment, which can contribute to improvement of symptoms [27].

In cases of ECU instability, conservative management should be attempted as well. This involves a period of immobilization in a pronated, extended, and radially deviated position for 6–8 weeks in order to maintain the ECU tendon in its groove. This may require a long arm cast if stability cannot be achieved in a short arm cast. [1, 2, 28, 29] Periodic stress examination and evaluation with ultrasound and/or MRI may be useful to ensure that there is healing of the ECU sheath. Continued instability indicates the need for continued immobilization or for surgical management [5].

Surgery is proposed by some investigators as the first-line treatment for acute traumatic ECU instability (especially in athletes) and is further indicated for cases that do not respond to conservative management [16]. Management depends on the type of subsheath injury that is encountered. In cases of periosteal avulsion, the avulsed periosteum should be reapproximated with transosseous fixation or suture anchors. When the sheath itself is torn or elevated from its insertion, direct repair may be attempted or reconstruction of the sheath should be completed using a strip of extensor retinaculum or periosteum [16, 17, 29, 30].

Complete rupture of the ECU tendon is uncommon in athletes. However, if this injury occurs in an active patient, reconstruction of the tendon with the use of palmaris longus graft should be considered [17].

Post operative care

Post operative management depends on the procedure performed. For procedures involving simple synovectomy with or without debridement, we recommend wrist immobilization for 2 weeks in a short arm splint. [17] If reconstruction of the ECU sheath as described above is performed, we recommend immobilization in a long arm cast for 4–6 weeks with the forearm in neutral rotation and elbow at 90°. We recommend restricting return to sport or vigorous activity for another 2 months after immobilization is discontinued and therapy has begun [16, 17].

Triangular fibrocartilage complex/distal radioulnar joint

Anatomy

The TFCC is composed of the triangular fibrocartilage (TFC), ulnar collateral ligament, the superficial and deep dorsal/volar radioulnar ligament, and the sheath of the extensor carpi ulnaris [31]. The superficial radioulnar ligaments become continuous with the ECU subsheath and the deep layer, often referred to as the ligamentum subcruentum, inserts into the fovea and the base of ulnar styloid.

Anatomically located between the ulna and the carpus, the TFCC serves as a load-bearing structure absorbing 18–20% of the load across the wrist [32]. In ulnar-positive morphology, however, the force transmitted across the joint is increased and conversely decreased in ulnar-negative morphology [33]. Additionally, force across the ulnar carpal articulation is increased with gripping activities and pronation of the wrist [33, 34•]. The thickness of the TFCC increases in ulnar-negative patients and decreases in ulnar-positive patients [35].

The TFCC is supplied by branches of the ulnar artery that penetrate the TFCC in a radial fashion from the volar, dorsal, and ulnar sides reaching the peripheral 10 to 40% of the TFCC. Subsequently, the central and radial portions are relatively avascular limiting their healing potential relative to the more peripheral portions [36].

Recent cadaveric studies demonstrate innervation of the TFCC by the dorsal cutaneous branch of the ulnar nerve (100%), medial antebrachial cutaneous nerve (91%), and the volar branch of the ulnar nerve (73%) [37•].

With respect to the DRUJ, it is generally agreed that the dorsal superficial radioulnar ligaments and the volar deep radioulnar ligaments tighten and stabilize the DRUJ in pronation. Conversely, in supination, the deep dorsal and superficial volar ligaments tighten [38]. While the bony articulation between the radius and ulna and the pronator quadratus stabilize the DRUJ as well, the focus of this review will be on the relationship of the stability of the DRUJ with respect to the TFCC.

Classification

Palmer first categorized TFCC injuries into traumatic or degenerative lesions and subsequently subcategorized them based on the location of the lesion [39]. The Palmer classification, however, does not classify all variations of peripheral TFCC tears specific to their impact on DRUJ stability.

Subsequently, Atzei et al. proposed a treatment-oriented approach to describing TFCC tears [40]. Their classification divides the TFCC into three primary structures: the proximal triangular ligament (ligamentum subcruentum), the distal hammock structure (superficial RUL), and the ulnar collateral ligament. Injuries are classified into five classes with corresponding suggested treatment (Table 1).

Diagnosis

Clinical exam

Patients presenting with pathology of the TFCC and DRUJ may recall a specific event indicating a traumatic injury. In more chronic, degenerative injuries, there typically is no inciting event. Pain is typically localized to the ulnar wrist and aggravated by activities that load the wrist or pronation/supination activities.

There are several physical exam techniques that have been described to assess the TFCC and DRUJ. Exam maneuvers include the piano key test, ulnocarpal stress test, pisiform boost test, press test, DRUJ ballottement, and dynamic examination of the ulnar head with active pronation and supination [41–43]. Additional tests, such as a positive ulnar fovea sign, may also indicate ulnotriquetral ligament injury [44]. These tests may elicit pain or detectable instability compared to the contralateral side which may help delineate the diagnosis.

Recently, the use of ultrasound to better determine the degree of displacement of the DRUJ has been proposed. This test is performed by manually stressing the DRUJ and measuring the displacement of the ulna relative to the radius. Comparing displacement to the contralateral unaffected wrist, the authors report 88% sensitivity and 81% specificity [45].

Imaging

Radiographs

Plain radiographs are typically part of the initial work up for patients and is helpful in identifying any underlying fractures, arthritic change, and gross malalignment. Particularly, determination of the ulnar variance and/or the presence of an ulnar styloid fracture are of interest in assessing the TFCC and DRUJ. Positive ulnar variance may predispose patients to ulnar impaction and degenerative tears of the TFCC. Often measured with the wrist in neutral, a pronated position with maximal grip effort results in further proximal migration of the radius increasing the ulnar variance [46]. Gapping between the distal radius and the ulna in this position compared to the contralateral side can also be assessed and is suggestive of DRUJ instability [47]. Additionally, in the case of distal radius fractures with associated ulnar styloid fractures, or in isolated ulnar styloid fractures, associated injury of the TFCC should be considered. Fractures involving the base of the ulnar styloid and displacement of 2–4 mm are more often associated with TFCC and DRUJ instability [48, 49••].

Magnetic resonance imaging

MRI is a commonly used imaging tool in the assessment of potential TFCC injuries. Conventional MRI has shown variable effectiveness with sensitivity ranging from 67 to 100% and specificity from 71 to 100% [50••]. Additionally, Iordache et al. performed a study of MRI scans on 103 asymptomatic

Table 1 Injuries classified into five classes with corresponding suggested treatment

Atzei classification [27]

Class	Injury	Treatment
0	Isolated ulnar styloid fracture without TFCC injury	Splinting, fragment removal in refractory cases
1	Isolated, peripheral tears of the distal hammock without DRUJ instability	TFCC suture
2	Complete tear of the proximal or deep fibers from the fovea resulting in positive hook test indicating loosening of the TFCC	TFCC foveal refixation
3	Complete tear of the proximal superficial and deep fibers resulting in positive hook test indicating loosening of the TFCC	TFCC foveal refixation
4	Non-repairable TFCC tear due to size of tear or tissue quality	Tendon graft reconstruction
5	TFCC tear in the setting of DRUJ arthritis	Arthroplasty

patients finding 39/103 (38%) had either a partial tear, complete tear, or MRI abnormality of the TFCC. Of note, the prevalence of an abnormal finding on MRI was significantly higher in the >50 year/old group [51]. Subluxation of the DRUJ as measured on axial MRI was proposed as another measurement to identify TFCC foveal disruption. Ehman et al. found that in patients with confirmed TFCC tears, there was significantly more dorsal subluxation of the ulna compared to healthy volunteers (16 vs 5%). With a cut off of 11% subluxation, the authors report a sensitivity of 62% and specificity of 91%.

Magnetic resonance arthrography (MRA) has also been employed in the diagnosis of TFCC pathology and has been shown to be superior to MRI alone. Lee et al. compared 3-T MRI to MRA in 37 patients with central TFCC tears and 15 peripheral tears. All tears were confirmed by arthroscopy. The authors showed an increased accuracy in the MRA group compared to MRI alone in the diagnosis of central TFCC tears (95.8 vs 77.1%) and peripheral TFCC tears (95.8 vs. 87.5%) [50••]. Similarly, in a more recent study by Pahwa et al. demonstrated 100% accuracy of MRA compared to 75% in MRI alone [52•]. Further supplementation of MRA has also been proposed including the use of traction to help increase visualization of the joint space. Lee et al. implemented the use of finger traps to apply traction during MRA and showed a significant improvement of visualization of the joint space as well as increasing accuracy of diagnosis compared to pre-traction assessment (98 vs 83%). Of note, this is in contrast to a previous study by Cerny et al. which did not show significant change in the ulna-TFC joint space [53•]. It should be noted that only 4 kg of traction were applied in this study compared to 7 kg for men and 5 kg for women in the study by Lee et al. [53•, 54••].

CT arthrography

CT arthrography (CTA) is an alternative imaging modality in the diagnosis of TFCC injury. In a cadaveric study of 10 specimens, Lee et al. demonstrated 100% sensitivity, specificity, and accuracy of CTA in the diagnosis of TFCC tears [55••]. Morimoto et al. subsequently described a CT arthrography protocol that visualizes the TFCC in multiple planes to better identify foveal TFCC lesions. They reported 83% sensitivity, 40% specificity, and 76% positive predictive value [56••].

Treatment

Surgical indications

In the absence of DRUJ instability, conservative management of TFCC tears is the first-line treatment. Bracing, taping, activity modification, and corticosteroid injections in chronic tears should be trialed first. [57] A recent study found that a period of 4 weeks of immobilization resulted in symptomatic relief in 57% of patients with TFCC pathology in one cohort [58]. If the patient fails conservative management then surgical intervention should be considered.

McAdams et al. reported a series of 16 competitive athletes undergoing TFCC debridement or repair and showed improvement in mini DASH scores and average return to play of 3 months. With this in mind, athletes should be advised that they are unlikely to cause irreversible damage if treatment is deferred until after their season. Thus, timing of intervention is largely dependent on the athlete's ability to perform at their desired level. Other considerations such as remaining time in the season, time left in their playing career, contract implications, social history, and playing time should all be part of the decision-making process in the high level athlete [59].

Operative treatment

Central tears Central tears of the TFCC that lack vascularity do not have the same healing potential as more peripheral tears and thus are treated with debridement to a stable edge [36]. Additionally, the use of thermocoagulation has been proposed as an adjuvant treatment in these conditions. Heat applied to the collagenous articular disc may lead to shrinkage and stabilization of the tissue changing the mechanical properties of the TFCC [60]. Additionally, the use of electrothermal treatments has been shown to eliminate neuronal markers in treated tissues suggesting denervation of the treated areas which may contribute to pain relief as well [61••].

In the setting of ulnar-positive variants, debridement alone may not fully address potential symptoms stemming from ulnar impaction or abutment. Concomitant ulnar shortening osteotomy (USO) or wafer procedure may be considered. Shortening the ulna decreases the load across the ulnar carpal joint and can help relieve symptoms stemming from any impaction of that joint [32]. In patients whom require <2–3 mm of shortening, a wafer procedure, either open or arthroscopic, can be considered. Potential advantages of the wafer procedure compared to USO include no need for bony healing, it avoids the use of hardware, has a more limited exposure, and potentially a faster recovery time [62, 63]. While the wafer procedure has shown comparable outcomes to USO, there has been no evidence of superiority of one procedure over the other [46, 64, 65]. However, in the setting of significant ulnar-positive variants (>2–3 mm) or patients with concurrent lunotriquetral instability, more significant shortening is required and USO is the treatment of choice. Ulnar shortening osteotomy specific hardware is available, which comprises of a low profile plate with a built in guide allowing for more precise cuts and reliable compression [66•].

Peripheral tears Peripherally located tears have more healing potential than central tears and thus are indicated for repair when conservative management has failed. Furthermore, disruption of the foveal attachment may result in DRUJ instability further necessitating surgical stabilization. Repair options include open and arthroscopic techniques. A case series by Nakamura et al. suggests that arthroscopically treated TFCC injuries may have better outcomes in acute injuries (<7 months) compared to chronic injuries (>7 months). In their series, there was no difference in measured outcomes based on chronicity of the injury in the group treated with open treatment [67]. Anderson et al. studied patients with peripheral TFCC tears and showed no difference in PRWE or DASH scores between open or arthroscopic techniques. Of note, only 27/75 patients included in the study were classified as having instability of the DRUJ [68]. Subsequently, a study conducted by Luchetti et al. looked at 49 patients with DRUJ instability and foveal detachment undergoing open or arthroscopic assisted TFCC repair. Both groups showed improvement of DASH and PRWE scores compared to preoperative scores. However, the arthroscopic group was found to have greater improvements when compared to the open group. The authors theorize that the use of a smaller capsulotomy with less local trauma and greater accuracy of suture anchor placement may contribute to better outcomes in the arthroscopically treated groups [69••].

Peripheral repair constructs Repair constructs rely on osseous fixation or capsular fixation. Atzei et al. retrospectively looked at patients with class 2 and 3 tears that were arthroscopically repaired using suture anchors. They showed significant improvement in MMWS and DASH scores as well as resolution of DRUJ instability in 91.7% of their cohort. [70•] Similarly, Kim et al. reported a series of patients with foveal detachments and ulnar-positive anatomic variants who underwent anchor fixation. They report significant improvement in MMWS scores as well as decreased dorsal ulnar subluxation postoperatively [71•]. Knotless systems using anchors have also been proposed with the theoretical advantage of diminished local irritation as there are no knots in this system [72•]. Desai et al. reported a series of patients using the knotless system or transosseous fixation. They report significant PRWE and DASH score improvement post operatively. However, the groups were not differentiated by fixation method [73].

All-arthroscopic, all-inside instrumentation is another proposed fixation method. Yao et al. reported a series of 12 patients with Palmer 1B tears via an all-arthroscopic, all-inside technique. This technique utilizes tools allowing for the deployment of poly-L-lactate blocks outside the capsule with a preloaded, pre-tied, self-sliding knot system. The authors report 11/12 patients had excellent Quick DASH scores (11 ± 12) and PRWE scores (19 ± 14). The authors propose the use of capsular fixation that does not rely on osteointegration may allow for earlier return to activity and accelerated rehabilitation. However, this was not directly explored in the study [74].

A number of biomechanical studies have been conducted examining the strength of various fixation techniques. Yao et al. demonstrated that all-arthroscopic, all-inside fixation has a higher average load to failure than suture capsular repair in a cadaver model [75]. A similar cadaver model was used to compare knotless suture anchors to PDS and found the knotless suture anchor group had a higher load to failure [76•].

Lastly, in irreparable TFCC tears due to tissue quality or size of the tear with concomitant DRUJ instability, graft reconstruction can be considered. The use of a palmaris graft or ECU half-slip to reconstruct the foveal attachment of the TFCC has the theoretical advantage of osseous integration of the tendon through bone tunnels [77•, 78•, 79•]. Nakamura et al. reported a series of patients undergoing ECU half-slip reconstruction with 21/25 patients with excellent outcomes and 22/25 with stable DRUJ [79•].

Radial-sided tears Due to the limited vascular supply to the radial portion of the TFCC, these lesions are often treated with debridement. If there is instability of the DRUJ, however, then repair is recommended. Sagerman and Short describe an inside out technique fixing the avulsed radial TFCC down via sutures through a bone bridge to the radial side of the radius [80]. If there is a residual cuff of TFCC, direct repair may be accomplished using curved or straight suture hooks to pass sutures across the tear [81].

Post operative care

Postoperative protocols are variable depending on surgeon preferences and the procedure that was done. If debridement is performed then typically 2 weeks of immobilization is performed. If a repair is performed, then an additional 4 weeks in a short arm or Muenster cast is utilized for a total of 6 weeks of immobilization. Progressive rehabilitation may begin at that time with return to play targeted at 3 months [82].

Conclusions/author's perspectives

Ulnar-sided wrist pain in athletes may often be a daunting diagnostic dilemma. However, with a thorough history and physical examination, and the use of supplemental imaging modalities, the diagnoses may be quite straightforward. Athletes should be treated as all patients but additional information such as the patient's preferred sport, where they are in their season and their career, and what their ultimate goals are (professional versus recreational) should be included when contemplating treatment. ECU injuries and TFCC/DRUJ injuries are quite common in patients whose sports require torsion and rotation of the wrist and forearm. These patients are ubiquitous in any hand specialist's practice. It is our hope that the guidelines as outlined above will help demystify what is often referred to the "black box" of the wrist: ulnar-sided wrist pain.

Compliance with ethical standards

Conflict of interest Eric Quan Pang declares that he has no conflict of interest.

Jeffrey Yao reports personal fees from Smith and Nephew Endoscopy during the conduct of study. He also reports personal fees from Arthrex, BME, McGinley Orthopedics, and Trimed, as well as a grant from Medartis, outside of the submitted work.

Human and animal rights and informed consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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