CASE REPORT

Stress injury of the lunate in tennis players: a case series and related biomechanical considerations

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Objective: To investigate clinical and imaging differential diagnosis and tennis stroke biomechanics potentially involved in lunate stress injury pathogenesis.

Methods: The present report describes five competitive tennis players with overuse-related dorsal wrist pain assessed by magnetic resonance imaging.

Results: Magnetic resonance imaging revealed the presence of lunate stress injury. All players were treated conservatively, with symptom resolution and complete functional recovery achieved at 14 weeks.

Conclusions: Lunate stress injuries should be considered in the differential diagnosis of overuse-related dorsal wrist pain in tennis players.

Wrist injuries are common among tennis players. They have been reported as the cause of 12.6% of on-site withdrawals from the professional men's circuit,¹ and the wrist is also the upper limb joint most often affected during Grand Slam tournaments.² In tennis players in general, most wrist injuries occur due to chronic overuse.³

Players often complain of dorsal wrist pain, which can in turn disrupt training and competition. The present report describes five cases of overuse-related dorsal wrist pain in tennis players, in whom MRI imaging studies revealed the presence of a lunate stress injury. To the best of our knowledge, this entity has not been previously analysed. Differential diagnoses and tennis stroke biomechanics potentially involved in lunate stress injuries pathogenesis are also discussed.

METHODS

Patients

Five young tennis players sharing similar clinical histories and symptoms, average age of 17.6 years (range 15–25 years), only one of whom was female, were identified between 2004 and 2006. All patients were right-handers, hitting one-handed forehand strokes and two-handed backhands, and reported pain on the dorsal aspect of the wrist during play. Four were competitive players at the junior level and one a full-time tennis coach. Patients referred with no prior history of wrist trauma; pain onset during tennis practice was gradual and insidious, particularly on execution of a forehand stroke, as well as during other sport activities requiring wrist hyperextension such as weight training (eg, bench-pressing). The typical overuse pattern was observed, worsening during activity and improving with rest. Two patients also referred concomitant minor ulnar-sided wrist pain.

On physical examination, symmetric active range of motion was normal in both wrists; however, forced passive extension of the affected wrist was painful. Tenderness was elicited at the lunate bone. Neurovascular status was normal, and specific provocative tests failed to show carpal instability in any of the five patients. Dominant handgrip strength measured

using the Jamar dynamometer revealed no significant impairment.

Imaging

Plain radiographs (PA neutral and ulnar deviation, true lateral, radial and ulnar oblique views) were interpreted as normal; ulnar variance was also determined. All patients underwent high-field (1.5 T) MR imaging with a wrist-dedicated coil, using a combination of STIR, T1 weighted, T2 weighted, proton density and T2 fat saturated (fat-sat) sequences. The main finding on all sequences (T1, T2, PD fat-sat, STIR, T2 fat-sat) was lunate bone marrow oedema without fracture line (fig 1A). The distal portion of the lunate bone was affected more often, and no signs of ulnar impaction were observed. All cases were classified as grade 3 lunate stress fracture according to the grading system proposed by Arendt.⁴ Three patients also underwent gadolinium-enhanced MR imaging, which failed to disclose signs compatible with carpal avascular necrosis.

Treatment and clinical outcome

Treatment consisted of semi-rigid wrist immobilisation for 6 weeks, non-steroidal anti-inflammatory drugs and physical therapy. Patients returned to tennis practice by 8 weeks, with symptom resolution achieved at 14 weeks, by which time all athletes had returned to competition. One male player presented mild discomfort at week 10, and an extra 2-week immobilisation period was instituted. Technical corrections were recommended, including switching the original "Western" forehand grip to an "Eastern" grip, as well as revisiting weight training exercise techniques. Control MR images obtained in three patients, showed partial bone marrow oedema resolution at 6 months, and normal lunate bone signal at 12 months (fig 1B).

Patients were evaluated for range of motion, subjective upper extremity disability perspective (DASH score),⁵ grip strength, and residual pain (VAS analogue scale). All patients achieved pain relief and returned to normal activity, including competitive tennis practice, remaining pain free 6 months after diagnosis. No wrist stiffness was noted. Clinical follow-up data are shown in table 1.

Patients were informed that data concerning their cases would be submitted for scientific publication, and institutional approval was obtained to this end.

DISCUSSION

Management of invalidating dorsal wrist pain can be challenging for sports physicians. Medical history should include all predisposing factors for bone stress injuries, as well as training habits and stroke biomechanics. A definite diagnosis is more readily established, if maximum point tenderness is identified. For dorsal areas of tenderness, wrist flexion allows better

Abbreviations: DASH, disability of the arm, shoulder and hand; ROM, range of motion

Figure 1 Grade-3 lunate stress injury of dominant wrist in a young male tennis player. A. Multiplanar MRI of the acute phase demonstrates diffuse lunate bone marrow oedema without cortical fracture line (grade 3 bone stress injury): (i) coronal T2-weighted fat suppressed (TR1 500/TE 60); (ii) coronal T1-weighted (TR 500/TE 20); (iii) axial T2-weighted (TR 4000/TE 60); (iv) sagittal T2-weighted (TR 3000/TE 60). B. Multiplanar MRI follow-up evaluation at 12 months shows complete resolution of lunate bone marrow oedema: (i) DP fat suppressed (TR 2000/TE 32.1); (ii) coronal T1-weighted (TR 520/TE 14.7); (iii) axial DP fat suppressed (TR 2740/TE 45.7); (iv) sagittal T1-weighted (TR 520/TE 11.9). Informed consent was obtained for publication of this figure.

palpation of the underlying structures. The presence of an occult dorsal ganglion is probably the most common cause of radial wrist pain in the tennis player, and should be suspected when point tenderness is found over the dorsum of the scapholunate joint.³ Other differential diagnoses that need to be ruled out in tennis players presenting overuse-related dorsal wrist pain are shown in table 2. Physical examination should

include all segments involved in the kinetic chain of tennis strokes.

Routinely performed, the radiographic evaluation is usually normal in young athletes with short-term wrist complaints due to overuse; anatomical variations, including ulnar variance determination are relevant when evaluating a tennis player with wrist pain.³ MR imaging remains however the technique of choice for the wrist, and is extremely sensitive in detecting bone marrow abnormalities.⁶ Schmitt *et al.*⁷ have reported Kienböck's disease as the most common cause of abnormal signal intensity in the lunate on MR imaging, followed by ulnolunate impaction syndromes and the presence of an intra-osseous ganglion (table 2). Bone marrow oedema is also the landmark finding in lunate stress fractures and should be differentiated from lunate osteonecrosis (table 3).

Upper limb stress fractures in tennis players are considered uncommon.^{8–10} However, stress fracture incidence in tennis players seems to be rising, probably due to higher diagnostic suspicion, longer and more intense training, and new stroke techniques.¹¹ In a retrospective cohort study, our group has reported an elevated absolute risk for stress fractures (12.9%) in elite tennis players over a 2-year study period. Upper limb injuries accounted for 22% of all injuries¹¹ including two lunate stress injuries (cases 1 and 2 of the present series; table 1).

In the present series, clinical outcome was satisfactory in all patients, with complete symptom resolution after 6 months of conservative treatment. Boden *et al.*¹² have classified stress fractures as belonging to one of two groups ("low risk stress fractures" or "high risk stress fractures"), depending on anatomical site, time to healing and propensity to union. Although lunate stress fractures have not been previously reported, they would appear to fall into the category of "low risk stress fracture" from the results observed in this limited case series, for which conservative treatment is primarily recommended.

The wrist functions as a stable mobile base, positioning the hand in space for sports activities like tennis strokes. Modern competitive tennis encompasses powerful actions, subjecting the skeleton to repeated high mechanical loads. A biomechanics analysis of tennis strokes is therefore relevant when treating overuse lesions, and could also help reduce re-injury risk. In the present study, factors predisposing to lunate stress injuries were analysed, focusing in particular on forehand biomechanics and anatomical features of the wrist joint such as

What is already known on this topic

- Overuse-related wrist pain is a common complaint among tennis players.
- The incidence of upper limb bone stress injuries seems to be rising due to higher diagnostic suspicion, more intense training and new strokes techniques.

What this study adds

- Lunate stress injuries should be considered in the differential diagnosis of overuse-related dorsal wrist pain in tennis players.
- Overloading of the wrist in extension and ulnar deviation (eg, forehand stroke) could represent factor contributing to the development of lunate stress injury.

Table 1 Descriptive results of lunate stress injuries in tennis players at 6-months follow-up

Case	Age/sex	MRI grade	ROM (°): extension/flexion/radial deviation/ulnar deviation/pronation/supination	DASH score	Grip strength (kg): dominant/non-dominant/two-handed	Return to tennis (weeks)
1	15/M	3	65/75/20/33/75/82	2	76/74/90	9
2	16/M	3	70/75/21/32/71/80	3	40/35/58	10
3	25/F	3	72/80/23/35/74/84	15	42/34/56	12
4	15/M	3	75/79/25/33/79/85	1	39/36/45	12
5	17/M	3	67/75/23/30/76/83	2	60/45/66	14

ROM, range of motion; DASH, disability of the arm, shoulder and hand.

Table 2 Differential diagnosis of lunate stress injuries in athletes^{7 20 21}

Dorsal wrist pain	MRI signal compromised lunate
Ganglion	Kienböck's disease
Dorsal impingement syndrome	Ulnolunate impaction syndrome
Kienböck's disease	Intra-osseous ganglion cysts
Tenosynovitis	Degenerative diseases
Carpal instability	Post-traumatic changes (bone bruise)
Ligament sprain	Others
Others	

ulnar variance measurement. All patients suffering lunate stress injuries referred pain when hitting a forehand. Elliot *et al.*¹³ have reported a 20% contribution of the wrist joint to final racquet velocity. Forehand stroke biomechanics involve 40° flexion–extension excursion of the wrist; on impact, the wrist is usually extended and in ulnar deviation, during the forehand groundstroke and the forehand volley.³ Furthermore, advanced players, similar to those included in this study, have demonstrated greater wrist extension on impact than beginners. Use of more a modern forehand stroke like the “Western” grip, has also been considered to increase loading to the hand and wrist.¹⁴ This hitting pattern involves greater elbow flexion, forearm supination, wrist extension and ulnar deviation than the “Eastern” grip, and might place the wrist joint at increased risk of overuse lesions such as lunate stress injuries. The combination of increased load on the wrist joint in extension and greater ulnar deviation have also been mentioned as a predisposing factors for Kienböck's disease.^{15 16}

How ulnar variance affects wrist load during tennis strokes is still not known. A compressive load across the wrist is transmitted mainly through the radiocarpal joint (82%), while a much smaller fraction is borne by the ulnocarpal joint (18%) while variance is neutral.¹⁷ Small changes in ulnar variance can however alter this force distribution markedly. Ulnar variance

also changes continually with forearm position and grip power,^{18 19} becoming increasingly more positive as power on the grip intensifies, and decreasing with full forearm supination. Ulnar-minus might allow greater wrist extension.¹⁶ A forehand stroke using the “Western” grip can decrease ulnar variance by positioning the forearm in supination and thus predispose to lunate damage.

In summary, lunate stress injuries should be considered in the differential diagnosis of overuse-related dorsal wrist pain in tennis players. Overloading of the wrist joint in extension and ulnar deviation, which can occur when executing forehand strokes during tennis playing or with weight training, could represent factors contributing to the development of these bone stress injuries, for which conservative treatment is recommended.

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Table 3 Differential diagnosis between Kienböck's disease and lunate stress injury^{20 21}

	Demographics	Clinical presentation	Aetiology	MR imaging	Natural history
Kienböck's disease	Young adults Males Manual workers dominant wrist	Gradual onset of pain Severe range of movement limitation	Avascular necrosis	Hyperintense signal of proximal lunate facet first. Gadolinium enhanced imaging (–)	Progressive to joint disruption if untreated Surgical treatment often required
Lunate stress injury	Adolescent competitive players Chronic overuse Dominant wrist	Gradual onset of wrist pain Worsened by hyper-extended activities Minor range of movement limitation	Bone resorption and formation imbalance	Distal facet of lunate first Gadolinium enhanced imaging (+)	Heal with conservative treatment

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COMMENTARY

This is an important paper stressing the presence of a significant cause of wrist pain in athletes, namely stress reaction/fracture. It is of utmost clinical importance that this entity is known, both to clinicians as well as radiologists. To differentiate this from lunatomalacia, from a radiological but more importantly from a therapeutic point of view, is essential.

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