Divergent Axial Carpal Dislocation and Its Pathomechanics

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Abstract

Background Axial carpal dislocations and fracture dislocations are 1.4 to 2.08% of all the fractures and dislocations of the wrist. These injuries are caused by high-energy blast or compression mechanisms. Only 11 cases of axial–radial–ulnar (ARU) fracture dislocations have been described in the literature.

Case Description We describe a case with a traumatic transtrapezoid, peritrapezium, transhamate, peripisiform ARU in a patient with acute compartment syndrome, traumatic transverse flexor retinaculum (TFR) rupture, and radial nerve palsy.

Literature Review The ARU fractures are injuries where the carpus is torn into three columns. ARU injuries have a high incidence of neurovascular, soft-tissue cover, and muscular-associated injuries. Depending on the injuries mentioned earlier, a bad functional prognosis can be expected. Nearly without exception, in ARU cases, a traumatic TFR rupture takes place. Garcia-Elias mentioned that the injury pattern is given by the speed, magnitude, and energy entry point.

Clinical Relevance We describe a case of an ARU injury which has not been previously described. In an analysis of the 12 ARU cases previously reported, we observed that when two or more applied forces converge, an ARU injury pattern can occur. That suggests that in ARU injuries, one side of the injury occurs before the other. Due to the extensive carpal damage, in patients with ARU, a restricted range of motion is more likely to happen than residual instability. Thus, in all these cases, an early mobilization and intensive rehabilitation is highly necessary.

Keywords

- carpal bones
- dislocations
- carpal joints
- compression mechanisms
- high-energy trauma

The axial carpal dislocations and fracture dislocations are rare injuries, accounting only 1.4% of all fractures and dislocations of the wrist.¹ These injuries are caused by high-energy compressive dorsopalmar forces.^{1,2} The most common injury mechanisms are crushing, blast, torsional, or a combination of all.^{3–5}

We divide axial carpal fracture dislocations in three different types as established by Garcia-Elias²: axial–ulnar

representing 58%, axial–radial representing 40%, and divergent axial–radial–ulnar (ARU) representing 2.5% of all axial carpal fracture dislocations.⁴ The divergent ARU fracture dislocations are rare injuries, with only 11 cases previously reported in the literature.^{2,5–12}

Most of these injuries primarily affect the distal carpal row.^{4,7} The proximal transverse carpal arch is almost always affected,^{3,8} including the capitolunate ligament with a

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Fig. 1 (A) X-ray taken at the time of admission shows only a clear axial–ulnar fracture dislocation (white arrow). (B) Postoperative X-ray clarifies a possible axial–radial–ulnar fracture dislocation (white arrows).

strength of 289 N which is one of the most commonly torn ligaments.³ The transverse flexor retinaculum (TFR) is broken or avulsed in most of these cases, not requiring a surgical decompression.^{1,3}

In this case, we describe a patient with a traumatic transtrapezoid, peritrapezium, transhamate, peripisiform ARU with acute compartment syndrome, TFR avulsion, and a radial nerve palsy. An injury like this has not been reported yet. We made a literature review to find the similarities of the 11 ARU reported cases and the case reported in this article.

Case Report

A 21-year-old, right-handed industrial male worker suffered a hand and wrist entrapment in a paperboard rolling press for a period of 15 minutes. He arrived at the hospital 13 hours after the accident. He was diagnosed with compartment syndrome of the hand and forearm, radial nerve palsy, and axial–ulnar dislocation. Hand and forearm fasciotomies and

closed reduction attempts were made (►Fig. 1). A computed tomography (CT; ►Fig. 2) showed an ARU accompanied with a hook of the hamate and trapezium ridge fractures.

A second surgical intervention was made, and using the third metacarpal bone and capitate as a reference, the second and fourth metacarpal bones, trapezoid sagittal fracture, and the capitolunate joint were reduced and fixed with K-wires and negative pressure therapy was applied. In the 3rd surgery, a skin graft was made.

The wrist was immobilized with a splint, free finger movement was allowed in the second week, and the splint and K-wires were removed in the fifth week. Intensive rehabilitation therapy was made for 12 weeks. Outpatient care with X-rays was made in weeks 2, 5, 12, and 24 (►Fig. 3). An electromyography indicating reinnervation of radial nerve was obtained at week 24.

Functional and self-assessment follow-up¹³ tests were made in the sixth and twelfth months, using the Mayo Wrist Score (MWS): 60 points in the sixth month and 65 points

Fig. 2 (A) In axial CT scan, we can clearly define (white arrows) the axial divergent dislocation, characterized in this case by the rupture of the trapezoid-capitate and capitolunate ligaments. Also the fracture of the trapezoid is seen. (B) Coronal CT scan shows the trapezoid sagittal fracture. (C) In coronal CT scan, we can see the incongruity in the capitolunate joint. We could define this injury as a transtrapezoid, peritrapezium, transhamate, peripisiform ARU.

Fig. 3 (A) One month postoperative X-ray shows a satisfactory reduction of the carpal joints. (B and C) X-rays taken at week 24 demonstrate a satisfactory carpal bones reduction and fractures consolidation.

satisfactory in the twelfth month. The patient-rated wrist evaluation (PRWE) was applied in its Spanish version¹⁴ in the sixth and twelfth months. The patient obtained 38.5/100 points and 28.5/100 points, respectively. As a final result, the patient obtained satisfactory ranges of motion (► **Fig. 4**).

Discussion

This case exemplifies the typical injury mechanism that involves an industry accident in a young worker's dominant hand, with axial compressive forces.^{1,2} The accurate diagnosis of these injuries is difficult in plain X-rays due to the bone superposition. CT scan is recommended as part of the diagnostic protocol without delaying the initial emergency management.^{1,3-5,12,15} It is also mandatory to make the differential diagnosis with perilunar or isolated carpal bone dislocations.³ In this case, due to the absence of a CT scan, the patient was undertreated in his first surgery. These mistreatments can lead to a bad functional outcome if no further studies are made.

Due to the amount of energy transmitted in ARU, the associated injuries are present almost in all cases, including neurovascular injuries that define the viability and outcome

of the hand. In this case, a radial nerve axonotmesis and volar retractile scars caused an incomplete extension recovery.

Loss of soft-tissue cover and compartment syndromes are common causes of a delay in the rehabilitation protocol.^{2,3,16} In ARU cases due to the extensive carpal damage, fibrotic scar formation occurs between carpal bones and intermuscular compartments. In these patients, a restricted range of motion (ROM) is more likely to happen than residual instability. Early mobilization and an intensive rehabilitation protocol are needed to obtain a good functional outcome. In this case, the compartment syndrome and soft-tissue cover losses caused volar retractile scars leading to an incomplete wrist extension ROM.

The TFR in this case was avulsed in two sites, confirming the theory that no surgical carpal tunnel decompression needs to be done.^{2,3,5,11,12}

The ARU fracture dislocations are the type of axial injuries with more complications and worst prognosis, due to the extensile carpal involvement and soft-tissue damage. In 2013, Garcia-Elias³ said that the injury pattern will depend on the angle formed between the applied force and the plain of the joint surface, the speed, the magnitude, the force

Fig. 4 Ranges of motion after 1 year: (A) wrist extension 25°, (B) wrist flexion 80°, (C) radial deviation 20°, (D) cubital deviation 25°, (E) full fingers extension, (F) grip almost fully closed.

Table 1 Principal characteristics of the 12 reported cases of ARU

Case	Author	Year	Mechanism	Additional Forces	Force direction	Associated injuries	TFR ^a rupture type	Diagnosis
1	Primiano and Reef	1974	Wringer crush	Rotation	Not cited	4, 5	Not cited	Not cited
2	Ali et al	1986	Crushing	Not cited	Not cited	1, 3, 4	Disrupted at several points	Peritrapezium + transhamate, peripisiform
3	Garcia-Elias	1989	Blast	Not cited	Not cited	1, 5, 6, 8	Trapezium ridge + hamate hook fracture	Peritrapezoid + transhamate, peripisiform
4	Pai and Wei	1994	Rolling	Hyperextension	Not cited	1, 2, 5, 8, 9	Not cited	Peritrapezoid, peritrapezium + capitate, hamate, pisiform
5	Pai and Wei	1994	Crushing	Hyperextension	Not cited	1, 2, 5, 6, 7, 8, 9	Not cited	Peritrapezoid, peritrapezium + transhamate, capitate, scaphoid
6	Pai and Wei	1994	Blast	Not cited	Not cited	5, 8, 9	Not cited	Peritrapezoid, peritrapezium + peripisiform
7	Irwin et al	1995	Rolling	Extension, supination	Ulnar to radial	Not cited	Not cited	Peritrapezoid, peritrapezium + transcapitate, perihamate, peritriquetum
8	Freeland and Rojas	2001	Crushing	Not cited	Not cited	3, 5	Not cited	Peritrapezoid, peritrapezium + perihamate, peritriquetum
9	Tanaka et al	2002	Crushing	None	Ulnar to radial	6	Not cited	Transscaphoid, peritrapezoid, peritrapezium + perihamate
10	Chim et al	2007	Crushing	Avulsion, rotation	Ulnar to radial, dorsal to volar	1, 2, 4, 6	Hamate volar dislocation	Perilunar dorsal + perihamate ulnar + peritrapezium. Radial
11	Gvozdenovic et al	2015	Crushing	Dorsal distraction, rotation	Distal-radial to proximal	6, 9	Trapezium comminuted + hamate hook fracture	Hamate dorsal avulsion fracture + peritrapezoid trans-trapezium
12	This study	2017	Crushing	Rotation, traction	Distal-ulnar to radial-proximal	1, 3, 4, 5	Trapezium ridge + hamate hook fracture	Transtrapezoid, peritrapezium + transhamate, peripisiform

Abbreviations: ARU, axial–radial–ulnar fracture dislocations; TFR, transverse flexor retinaculum.

Note: We can see that almost all cases have associated injuries. In most recent cases, mixed injury mechanisms are referred to produce an ARU.

^aTransverse flexor retinaculum. 1, peripheral nerve injury; 2, vascular injury; 3, compartmental syndrome; 4, soft-tissue cover loss; 5, tendon injury or muscle loss; 6, metacarpal fractures; 7, other noncarpal fractures; 8, finger amputation; 9, carpo-metacarpal dislocation.

entrance point, and the relative strength of bone and ligament structures.^{1,3}

Starting from those principles, and making a review of all the reported ARU fracture dislocation cases, schematized in ►Table 1, we think that for a divergent ARU fracture dislocation to be made, some features have to happen:

1. All the ARU fracture dislocations are produced by the combination of two or more injury mechanisms. Each side of the ARU can be produced by a different injury mechanism.
2. In ARU fracture dislocations, one side of the injury is always produced before the other.

In this case, as in the most recent cases, we can exemplify that two or more injury mechanisms have to converge.^{5,11,17} In the case presented in this article, the main applied force was axial compression in association with traction and

rotational forces given by the rolling press. The starting point was his fourth and fifth fingers, producing a gross dislocation advancing to the other side producing dislocation and a sagittal fracture of the trapezoid.

Understanding the injury mechanism can help us know the injury pattern, and suspect for specific associated injuries, which would in turn help us in our decision making and in the sequential reduction and fixation algorithm.

Conclusion

The ARU divergent fracture dislocations are not well-known injuries and can be easily disregarded. A CT scan is mandatory for a better treatment planning. More biomechanical studies need to be done for the complete understanding of these challenging injuries.

Due to the extensive carpal damage in these patients, a restricted ROM is more likely to happen than residual instability; thus, early mobilization and an integral rehabilitation protocol need to be done.

Conflict of Interest

None.

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