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Lunate dislocations: anatomy, diagnosis and management

Madeleine Garner[1]
Branavan Rudran[2]
Amir Khan[2]
Quen Tang[1]
Philip Mathew[1]

Author details can be found at the end of this article

Correspondence to:
Madeleine Garner;
madeleine.garner1@nhs.net

Abstract

Lunate dislocation is an uncommon but serious wrist injury, often resulting from a high energy mechanism of trauma. Advanced trauma life support protocols should be followed to diagnose and treat concomitant life-threatening pathology. Thorough neurovascular and soft tissue examination is required to identify open wounds and median nerve dysfunction, including acute onset carpal tunnel syndrome. Imaging is undertaken to appreciate injury severity, which is graded by the Mayfield classification. Closed reduction in the emergency department is the initial management, which alleviates pressure on neurovascular structures. Definitive management is surgical, most commonly via open reduction and direct ligamentous stabilisation. The aims of surgery are to restore anatomical carpal alignment and maintain stability, allowing repair and healing of the important wrist ligaments. Medium- to long-term functional outcomes are adequate, with most patients returning to work within 6 months. However, progressive radiographic midcarpal arthrosis is common, as well as permanent loss of grip strength, range of motion and chronic pain. This article considers the anatomy, diagnosis and management of acute lunate and perilunate dislocations.

Key words: Anatomy; Diagnosis; Lunate dislocation; Management; Perilunate dislocation

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Introduction

Acute lunate and perilunate dislocations are uncommon and often easily missed. They can broadly be divided into greater arc (bony fracture) and lesser arc (ligamentous) injuries. If neglected, they can cause significant detriment to hand function. The mechanism is typically from an axial compressive force in wrist extension and ulna deviation with inter-carpal supination (Mayfield, 1980). They typically result from high-energy impact such as road traffic accidents, falls from a significant height or contact sport injuries, and are frequently associated with concomitant life-threatening trauma to the thorax, abdomen, head and long bones (Herzberg, 2008). Such injuries should be managed emergently, before assessment and treatment of the carpal injury. This article considers the anatomy, diagnosis and management of acute lunate and perilunate dislocations.

Anatomy

The lunate, named after its crescent appearance, lies in the centre of the proximal carpal row and the longitudinal chain, forming an intercalated segment lacking tendinous insertions. It is described as the 'keystone' of the carpus as it is essential for carpal stability and motion, as well as understanding the pathoanatomy of lunate dislocations (White et al, 2016).

Within the proximal carpal row, the lunate articulates with the scaphoid radially and the triquetrum ulnarly. The longitudinal chain represents the relationship of the lunate to the radius proximally and the capitate distally (Figure 1). The wrist ligaments are broadly divided into intrinsic, between the carpal bones themselves, and extrinsic (volar and dorsal), bridging the proximal carpal row between the radius, distal radio-ulnar joint and distal carpal row (Taleisnik, 1976). The volar extrinsic ligaments (Figure 2) comprise the radiocarpal ligaments (the radioscaphocapitate, and long and short radiolunate ligaments) and the ulnocarpal ligaments (the ulnolunate and ulnotriquetral ligaments), which play an important role in stabilising the wrist (Taljanovic et al, 2012). The divergent arrangement

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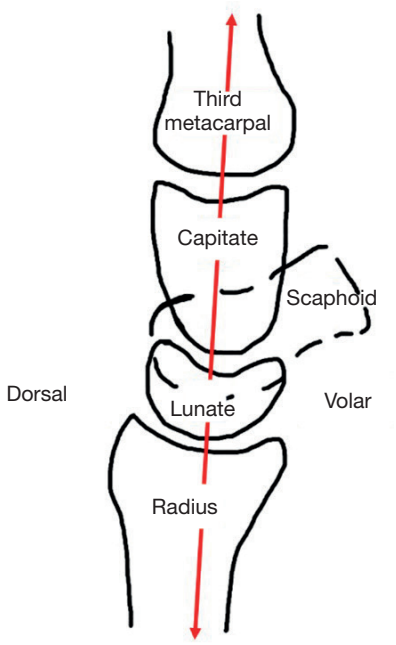

Figure 1. Schematic lateral view of the wrist. The lunate lies within a longitudinal chain, representing a 'keystone'.

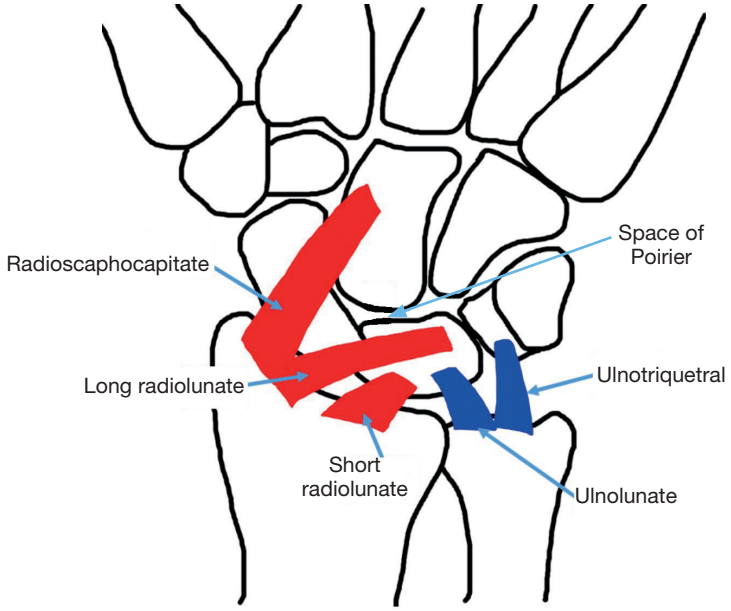

Figure 2. Key volar extrinsic ligaments of the wrist. Radiocarpal ligaments are shown in red and ulnocarpal ligaments are shown in blue.

of the volar extrinsic and intrinsic ligaments forms an area of weakness at the level of the proximal capitate, namely the space of Poirier.

The most important intrinsic ligaments relating to the lunate are the scapholunate and lunotriquetral ligament, which individually consist of volar, interosseous and dorsal components (Scalcione et al, 2014). The dorsal component of the scapholunate ligament and the volar component of the lunotriquetral ligament are the most robust, but all parts act to maintain lunate stability by balancing the forces exerted upon it. Unlike the distal row intrinsic ligaments which are stout, creating a rigid construct, these proximal intrinsic ligaments allow flexion and extension of the proximal carpal bones during wrist movement. Disruption of any one component of the carpal chains, bony or ligamentous, will affect movement of the entire segment.

Initial assessment

The presentation of acute lunate and perilunate dislocations can vary depending on the mechanism of injury, but they commonly result from high impact trauma such as falls from a height and road traffic accidents (Leung et al, 2014). Patients are typically working-age men (Leung et al, 2014), and a small study found that 32 out of 65 cases involved people who worked in manual labour (Israel et al, 2016).

Following a systematic assessment using the Advanced Trauma Life Support protocol (ATLS Subcommittee et al, 2013) and management of any life-threatening injuries, if suspicion exists, a focused history and wrist examination must be completed. An appreciation of the patient's functional baseline guides the multidisciplinary team towards appropriate goal-orientated treatment and rehabilitation.

On inspection, an open injury should be excluded. Open dislocations are reported in around 10% of cases (Adkison and Chapman, 1982; Herzberg, 2008) and prompt management using the BOAST open fractures guideline should be instigated (British Orthopaedic Association and British Association of Plastic, Reconstructive and Aesthetic Surgeons, 2017). The digits are often held in a semi-flexed position. Attempted palpation of a displaced lunate is painful and of little diagnostic use, as a result of generalised swelling and bruising (more marked in delayed presentations) and thick palmar soft tissue structures hindering examination (Figure 3). The rest of the hand, wrist, forearm and elbow must be assessed to rule out any concomitant injuries.

Neurovascular examination is essential during the initial assessment. The median nerve is the neurovascular structure most frequently damaged in lunate dislocations, normally manifesting as a sensory dysfunction. Although the incidence varies, neurological dysfunction has been reported in up to 50% of cases (Wickramasinghe et al, 2015). Median nerve symptoms can occur immediately at the time of injury as a result of traumatic contusion, but frequent reassessment is required to identify evolving symptoms related to oedema, haematoma formation or direct pressure from the displaced lunate causing acute carpal tunnel syndrome.

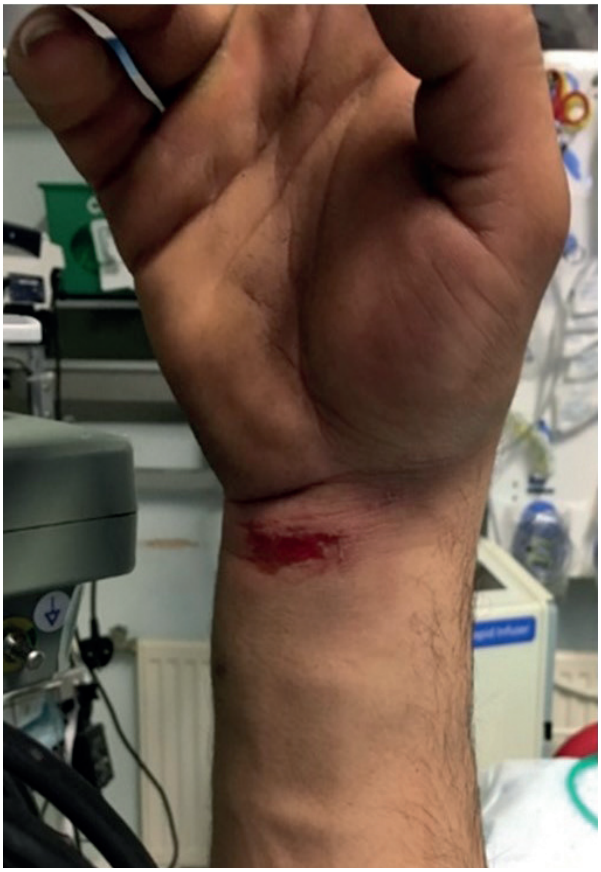

Figure 3. Signs of lunate dislocation: swelling and semi-flexed position of digits.

Further targeted investigation is important in the form of two plain radiographs: a true posteroanterior and true lateral view of the wrist. The posteroanterior view must be performed with the shoulder abducted to 90° and the elbow flexed to 90°, with the hand and shoulder at the same level. This gives a true posteroanterior view of the wrist, without any pronation or supination which may hinder interpretation. If more than one fracture is suspected and there is no neurovascular emergency (or it has already been planned that the patient will have a computed tomography scan of another injured body part) a computed tomography scan can help demonstrate other associated wrist injuries and plan treatment better.

Almost a quarter of injuries are initially missed as a result of non-specific signs and symptoms and limited experience by clinicians (Çolak et al, 2018). This leads to a significant socioeconomic burden because of the loss of productivity at work. Prompt diagnosis is key to successful recovery, so a low threshold for investigation is required.

Pathoanatomy and classification

Lunate dislocations are at the severe end of a continuum of perilunate injuries. The final injury is determined by the vector of the combined forces, size and duration of these forces (Mayfield, 1980).

Mayfield et al (1980) described a classification relating to the degree of instability for perilunate injuries, based on a series of sequential and progressive events disrupting the carpal chains (**Table 1**, **Figure 4**). In stage I, the distal carpal row hyperextends and pulls the scaphoid into extension, while the lunate stays fixed to the radius by the strong, short radiolunate ligament. The scapholunate ligament then ruptures, palmar component then dorsal, leading to scapholunate dissociation. The unopposed action of the lunotriquetral ligament leads to dorsal tilt of the lunate. Stage II involves disruption of the volar joint capsule as it bridges the space of Poirier. The force transmission continues, allowing the capitate to subluxate dorsally from the proximal carpal row. Stage III injuries (perilunate dislocation) occur as the triquetrum is pulled dorsally by the capitate, resulting in failure of the lunotriquetral ligament, causing the capitate to now dislocate dorsally. Finally, in stage IV (lunate dislocation), the strong volar extrinsic ligament pulls the dorsally displaced capitate volarly and proximally. The resultant force from the capitate dislocates the lunate volarly through the space of Poirier, into the carpal tunnel. At this point, the capitate can fall into the vacated lunate fossa of the radius. The lunate entering the non-expansile carpal tunnel can result in an acute carpal tunnel syndrome and median nerve damage.

At all stages failure can be ligamentous, osseous or both. Johnson (1980) described the region of potential perilunate injury as the 'zone of vulnerability' and divided these vulnerable areas into two arcs (**Figure 4**). Lesser arc injuries have purely ligamentous disruption, whereas greater arc injuries include perilunate fractures, most commonly trans-scaphoid.

Imaging

Plain radiographs of the wrist are the initial imaging of choice and permit injury staging as per Mayfield's classification system (**Table 1**).

Gilula (1979) proposed a systematic approach to scrutinise these films, looking for evidence of both lesser and greater arc injuries. On a posteroanterior film, three smooth concave arcs can be drawn, defining normal carpal alignment (**Figure 5**). Disruption or 'crowding' on a true, posteroanterior film suggests a lesser arc injury. Such disturbances include widening of the scapholunate gap to greater than 3 mm ('Terry Thomas' sign) and scaphoid foreshortening, giving a 'signet ring' density because the proximal and distal poles appear superimposed, both of which suggest Mayfield stage I injuries. These stage I signs are subtle and, crucially, Gilula's three arcs may appear grossly undisturbed despite underlying injury. On a lateral radiograph, assessing collinearity of the radius, lunate and capitate is key. The 'spilled teacup' sign is pathognomonic for lunate dislocation (stage IV) and represents complete loss of collinearity of the lunate with the radius and capitate as it rotates and moves volarly into the space of Poirier (**Figure 6a**). The radius and capitate may well appear colinear with each other, giving false reassurance, as the capitate is pulled into the lunate fossa. On the posteroanterior film, the normal 'trapezoidal' lunate

Table 1. Pathological progression to lunate dislocation. Mayfield and Johnson classification systems

Stage	Lesser arc injury (ligamentous)	Greater arc injury (osseous)	Pathoanatomy	Mechanism of injury	Radiographic signs (White et al, 2016)
I	Scapholunate	Radial styloid Scaphoid	Scaphotrapeziotrapezoid ligament extends scaphoid but short radiolunate ligament restricts lunate rotating scapholunate ligament ruptures Scapholunate dissociation Lunotriquetral ligament tilts lunate dorsally	Wrist hyperextension Ulnar deviation Scaphoid rotary subluxation	Anteroposterior: Terry Thomas sign, signet ring sign Lateral: scapholunate angle >70° normal 30–60°
II	Volar joint capsule	Capitate	Capitate subluxates dorsally Space of Poirier widens Longitudinal chain broken	Lunocapitate dissociation	Posteroanterior: Gilula's arc interrupted (Gilula, 1979) Lateral: loss of sagittal collinearity of longitudinal chain
III	Lunotriquetral	Triquetrum	Triquetrum and capitate dislocate dorsally Perilunate dislocation	Triquetrum extension Perilunate dislocation	Posteroanterior: Crowding (triquetrum overlaps lunate and hamate)
IV	Radiotriquetral	Ulnar styloid	Volar lunate dislocation through space of Poirier Short radiolunate ligament acts as hinge for rotation	Radioscaphocapitate ligament (strong) pulls capitate volarly, back into the central longitudinal chain. Pushes lunate volarly	Posteroanterior: Piece of pie sign Lateral: spilled teacup sign and capitate articulates with distal radius

Direction of injury propagation (radial to ulnar)

From Mayfield (1980), Mayfield et al (1980)

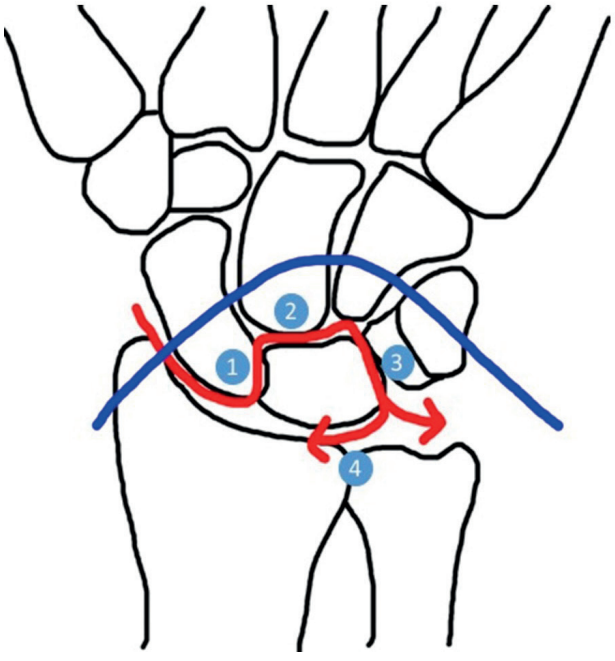

Figure 4. Direction of injury propagation as described by Mayfield stages 1–4 (**Table 1**). Red line = lesser arc injury; blue line = greater arc injury.

will appear wedge shaped, like a piece of pie (Figure 6b), because of its rotation around the fulcrum of the short radiolunate ligament. In perilunate dislocation (stage III), it is important to recognise that the lunate is still located in line with the radius on the true lateral view, which is a key differentiating feature from a lunate dislocation (stage IV). High resolution computed tomography and non-contrast magnetic resonance imaging are essential in identifying subtle lesser arc injuries and occult fractures, and are paramount in preoperative planning (Taljanovic et al, 2012; Scalcione et al, 2014).

Initial management

The initial management of perilunate and lunate dislocations requires immediate closed reduction with longitudinal traction and the Tavernier's manoeuvre (Figure 7) (Tavernier, 1906). This ensures pressure is alleviated from surrounding structures, in particular the

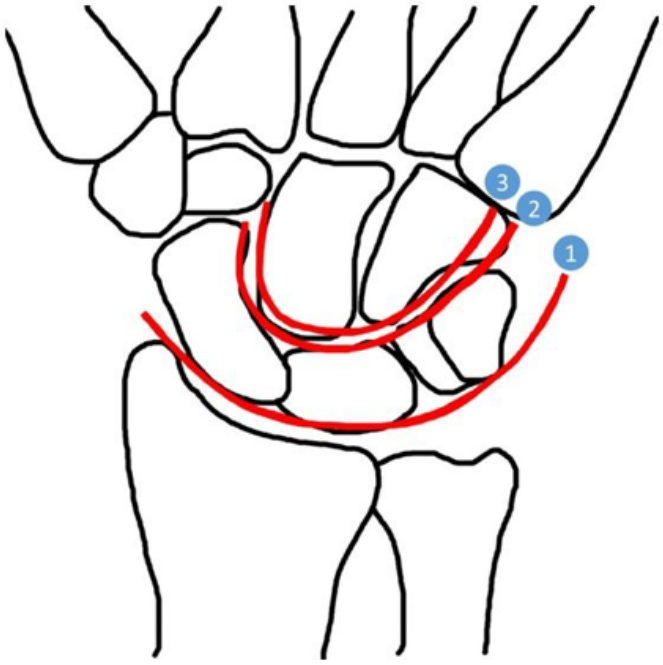

Figure 5. Gilula's three arcs. 1 follows the convex proximal surfaces of the proximal carpal row. 2 follows the distal surfaces of the same bones. 3 follows the proximal surface of the capitate and hamate.

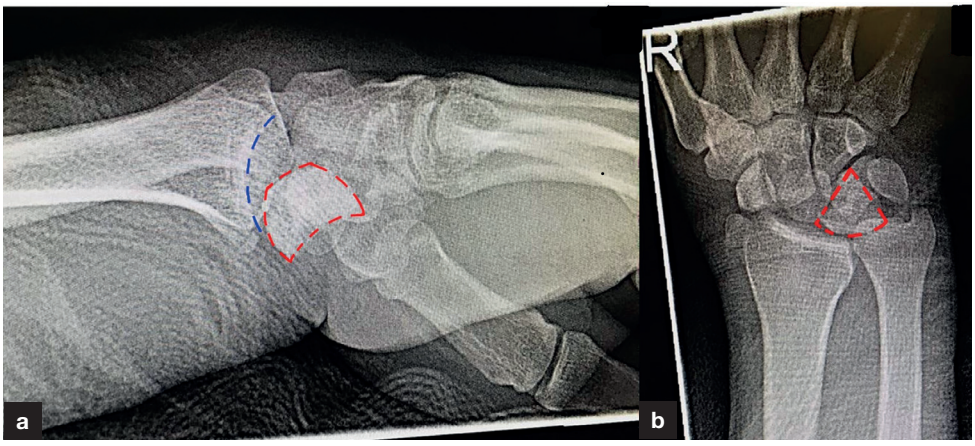

Figure 6. Right wrist lunate dislocation. a. Lateral radiograph of the right wrist demonstrating the 'spilled teacup' sign. Red line = rotated lunate (spilt teacup); blue line = distal radius (saucer). The capitate aligns with the radius. b. Posteroanterior radiograph. Red line = rotated lunate (piece of pie sign). There is loss of Gilula's arcs and associated greater arc injury (radial styloid and scaphoid fractures).

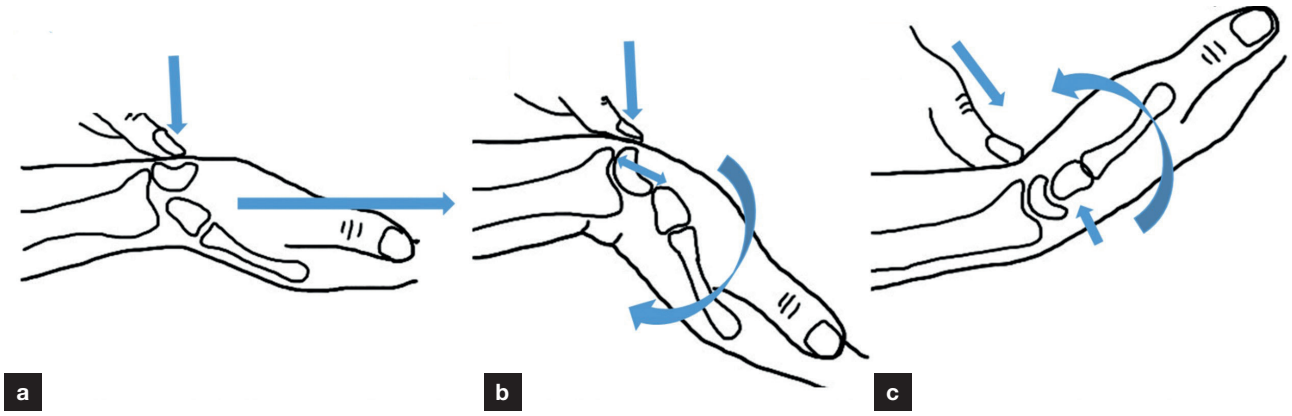

Figure 7. Tavernier's manoeuvre (closed reduction). a. Longitudinal traction and firm pressure over the lunate. b. Wrist extension and sustained distraction. c. Wrist flexion: guide lunate into position and allow capitate to resume its position.

median nerve, osseous vasculature and cartilage. This is most effectively performed with the arm flexed at 90° at the elbow, the fingers suspended within finger traps and traction applied (Figure 8). Appropriate sedation and analgesia should be administered to overcome muscle spasticity (Stanbury and Elfar, 2011).

Various reduction manoeuvres (Tavernier, 1906) are described in the literature, all following the fundamental principles of exaggerating then reversing the deformity (Figure 7). The surgeon places their thumb over the volar aspect of the lunate and with ongoing distraction, gently extends the wrist, opening the space of Poirier and the space between the radius and capitate. Then, with firm pressure the lunate is guided into its anatomical location while the wrist is gently flexed to allow the capitate to resume its position on the lunate. A cast is applied to maintain reduction with a post-reduction radiograph to confirm the anatomical position. Failed reduction may be secondary to inadequate muscle relaxant or mechanical

Figure 8. Urgent closed reduction. Longitudinal traction and counter traction are applied using finger traps.

obstruction, such as interposed soft tissue or a lunate rotated over 90° (Kim et al, 2015). Failure to reduce an acute lunate dislocation or perilunate dislocation is an orthopaedic emergency, which often requires open reduction and decompression of the carpal tunnel.

Operative management

Cast immobilisation alone is often insufficient to achieve and maintain an 'anatomical', stable reduction, and is associated with poor outcomes including chronic carpal instability and post-traumatic arthritis (Israel et al, 2016). Definitive management using an open approach is the mainstay of treatment and allows direct visualisation of the carpal bones (Najarian et al, 2011). There is currently no consensus on whether a dorsal, volar or combined approach is best. The dorsal approach provides the optimum view of the carpal bones, as often the entire ligament complex has been stripped off. Kirschner (K-) wires can be used to joystick and then hold the scaphoid and lunate reduced in anatomical alignment. Further K-wires are then passed to maintain this relationship, including through the capitate and triquetrum (Najarian et al, 2011). These K-wires maintain the carpal alignment while performing repair of the ruptured ligaments, and can be kept temporarily in situ postoperatively to augment stability and relieve tension on the repaired ligaments during their critical healing period (Weil et al, 2006).

A volar approach permits release of the pressure on the median nerve with carpal tunnel decompression, while aiding lunate reduction and enabling repair of the structurally important volar, extrinsic capsular ligaments.

Any associated fractures will need to be treated at the same time in greater arc injuries and this is usually best achieved through open reduction and internal fixation.

Arthroscopically-assisted percutaneous reduction and fixation is an emerging option, especially in low-grade Mayfield and greater arc injuries. This enables good visualisation of osteoligamentous pathology, with reduced surgical insult to the soft tissue. Preservation of the tenuous carpal vasculature is thought to enable ligamentous healing and maintenance of carpal stability via good approximation of capsular structures alone, without the need for direct repair (Kim et al, 2015). Nevertheless, if direct ligamentous repair is indicated, open access is often required. This arthroscopic approach has a steep learning curve and the procedure requires significant technical expertise.

In late presentations or missed diagnosis, open reduction and ligament reconstruction seems to be the best treatment (Dhillon et al, 2011). Salvage options such as proximal row carpectomy, wrist arthrodesis and lunate excision should only be considered when degenerative changes are noted, for example significant chondral damage or in injuries older than 5 months, as poorer results have been seen with reconstruction in this cohort of patients (Dhillon et al, 2011).

Outcome measures and complications

Lunate and perilunate dislocations are severe injuries that have the potential to cause long-term, debilitating complications. After early surgical restoration of carpal anatomy and ligamentous stability, medium- to long-term patient-reported outcomes are generally satisfactory. However, patients rarely recover to their functional baseline in terms of grip strength and range of movement and persistent pain, although often not severe, is common (Stanbury and Elfar, 2011). A retrospective study (n=65) found patients had a mean quickDASH score of 21 (score ranges from 0 (no disability) to 100 (most severe disability)) 8 years post-surgery (Israel et al, 2016). Another smaller series (n=18), with a 13-year follow up, found patients had an average Mayo wrist score of 76 (score ranges from 0 (worst function and pain) to 100 (normal function, no pain)) (Forli et al, 2010). Both these scores signify relatively good overall function, consistent with occasional, activity-related mild to moderate pain. The majority of patients returned to their original occupation, including manual labour, within 6 months (Herzberg, 2008; Israel et al, 2016).

There is discordance between clinical symptoms, or lack of, and the extent of radiographic arthritic pathology in the medium and long-term follow-up period. Radiographically, post-traumatic arthritis is common and increases with length of follow up time (Forli et al, 2010;

Key points

- Lunate and perilunate dislocations are uncommon and easily missed. If suspected, specialist input should be sought to aid early diagnosis.
- Perilunate disruption (ligamentous or osseous) will affect stability, movement and function of the wrist.
- Injuries occur in a sequential, predictable pattern with characteristic radiological signs, culminating in lunate dislocation into the carpal tunnel.
- Early diagnosis and treatment may prevent or decrease the chance of median nerve dysfunction, post-traumatic wrist arthrosis, instability and fracture non-union.
- Open reduction and ligament stabilisation is the definitive management and leads to better functional outcomes. This is best performed by a specialist hand surgeon.

Israel et al, 2016). The prevalence of radiographic radiocarpal and midcarpal degenerative change in patients who underwent early open reduction and internal fixation was around 20% at 2 years, and over 50% at 8 years after injury. It is important to reiterate that the majority of these patients had little functional deficit, despite the radiological findings (Forli et al, 2010; Israel et al, 2016).

Chronic median nerve dysfunction does not often feature when timely reduction or carpal tunnel release is performed in patients presenting with neurological deficits (Herzberg and Forissier, 2002; Wickramasinghe et al, 2015). High grade Mayfield scores, delayed diagnosis and poor anatomical reduction indicate poor prognosis, as a result of complications arising such as transient lunate ischaemia, osteonecrosis, chondrolysis, chronic perilunate instability and complex regional pain syndrome. Approximately 26% of patients require revision surgery, namely arthrodesis, screw removal or bone grafting for carpal non-unions (Israel et al, 2016).

Conclusions

Lunate and perilunate dislocations result in serious insult to the wrist and have a guarded prognosis. Despite progressive radiographic changes featuring on follow-up imaging, as well as reduction in grip strength and range of motion in these young adult patients, patient-reported outcome measures generally indicate adequate return of hand function after early, definitive surgical management. These conclusions are based on current available data, which are limited to small, retrospective case series. Larger prospective or multicentre studies would be helpful for assessing different management techniques for these injuries.

Conflicts of interest

The authors declare that they have no conflicts of interest.

Author details

[1]Department of Trauma and Orthopaedics, Chelsea & Westminster Hospital, London, UK

[2]Department of Trauma and Orthopaedics, Royal National Orthopaedic Hospital, London, UK

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Curriculum checklist

This article addresses the following requirements from the core surgical training curriculum:

- Managing an acute unselected take
- Peri-operative management of emergency orthopaedic patients
- Interpretation of radiology of musculoskeletal trauma.

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