

Advances in Kienbock's Disease: Imaging and Arthroscopy

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Abstract

The treatment of Kienbock's disease has remained a clinical challenge since its original description over 100 years ago. We present our concepts on pathoanatomy and the role of new imaging modalities. Arthroscopic assessment remains the "gold standard" for the assessment of the lunate and wrist. We present our classification and algorithm as a management aid to the treating surgeon. In addition, we outline the indications and techniques of a number of arthroscopic procedures used to treat the Kienbock's wrist.

Keywords: Kienbock's disease; arthroscopy; Imaging

Introduction

Kienbock's Disease (KD)- The Enigma

Since its original description in 1910, the etiology, pathogenesis, and natural history of KD have remained an enigma [1]. Lichtman's original classification of KD advanced the understanding of the disease and the pattern of involvement to the lunate and surrounding carpal bones [2]. It also provided a management framework for the treating surgeon. Surgical treatment has traditionally fallen under two schools of thought; to improve vascularity to the compromised lunate, or to improve mechanics and "offload" the lunate. The literature lacks homogeneity and has been limited to small series with variable follow-up intervals. Until recently, therefore, there has been little clarity on the best treatment option for this rare but debilitating condition. We recently published our theories on the etiology and pathogenesis of KD [3], and in conjunction with Dr. Lichtman, presented a new algorithm - respecting the chondral, osseous, and vascular elements of the disease [4, 5, 6, 7, 8]. As well as classifying the disease state and extent of involvement, we also present pragmatic surgical options; the best

treatment for one patient may not be the same as another. Optimal management encompasses the skills, resources, and training of the treating surgeon, as well as the age, comorbidities, and function demands of the patient. We have used arthroscopy as an essential tool in the assessment and treatment of KD for over 20 years. We believe arthroscopy represents the "gold standard" in assessment of the chondral surfaces [9]. As our understanding of the disease has evolved so has our arthroscopic approach to treatment. In successfully treating patients with KD, the treating surgeon needs an understanding of the disease state of the lunate, surrounding carpus, wrist biomechanics, and disease activity. Computed tomography (CT) shows osseous detail, collapse, and fracture lines. Magnetic resonance imaging (MRI) with contrast shows vascular perfusion and bone marrow signal and gives prognostic information. Newer modalities such as 4D-CT allow improved understanding of the biomechanics of the Kienbock's wrist. Single-photon emission CT (SPECT-CT) scanning can be diagnostic and highlights disease activity in the lunate and surrounding carpus, as well as giving

anatomical detail [10]. We present our pathoanatomy concepts and approach to a Kienbock's patient following clinical assessment. We will highlight these innovations in imaging as well as our arthroscopic approach and treatment algorithm.

Pathoanatomy

Characteristic findings can be found on imaging and arthroscopy. The wrist articulation comprises three columns, two carpal rows, and a wide joint surface. There are a number of intercalated segments or osteoligamentous "rings." These form a kinetic chain and allow for shared load transmission throughout the range of motion.

A collapsing lunate compromises the wrist as follows [3,8]:

1. Central column deformation, collapse, and proximal row instability Lunate comminution or a coronal fracture allows proximal migration of the capitate. The scapholunate and lunotriquetral ligaments strain or tear as a result of lunate shortening and tilt. Loss of height of the central column results in shortening of the radial column as the scaphoid flexes. The lunate may flex or extend depending on the extent of osseous disruption and direction of force through the lunate from the capitate, and the scapholunate ligament is now torn.
2. Degenerative changes at the radiocarpal joint Fractures of the lunate subchondral bone plate produce irregularity at the lunate fossa. Degenerative changes then progress in the radial direction; excessive scaphoid

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Figure 1: 4D computed tomography showing motion of the carpus in full ulnar (left) and radial (right) deviation (Copyright Dr. Gregory Bain).

Figure 2: Clenched fist view - open fist (left) and clenched fist (right): The lunate position does not change on stress making it susceptible to a “stress fracture” of the radial half of the lunate (Copyright Dr. Gregory Bain).

flexion leading to incongruence at the radioscaphoid articulation and degenerative changes at the scaphoid fossa.

3. Degenerative changes at the midcarpal joint and “KDAC” Kissing lesions occur between the capitate and lunate facet and degenerative changes progress with further fragmentation of the lunate. Once there is significant involvement of both carpal rows and two or more columns, KD advanced collapse - “KDAC” has occurred and a salvage procedure is now required.

Innovations in Imaging

Recent developments in radiology have improved our assessment of KD. Standard imaging for KD includes the following:

- Plain radiographs- first-line allows for the assessment of wrist morphology; ulnar variance, lunate size and shape, radial inclination, radioscaphoid angle, gross evaluation of degenerative change, sclerosis, and collapse.
- CT- allows more accurate assessment of osseous and perilunate disease and staging.
- MRI with contrast -unenhanced MRI allows detection of abnormal marrow signal. In the early stages of KD, edema in the lunate shows as increased signal in T2- and decreased signal in T1-weighted images.

Thereafter, as the disease progresses, decreased signal is present on both T1- and T2-weighted. Unenhanced MRI, therefore, is limited as there is no differentiation between intercellular (reversible) and intracellular (cytotoxic edema). It also fails to assess the repair zone [11].

MRI with contrast and hyperenhancement with gadolinium indicates maintained vascular perfusion. We use the classification as described by Schmitt [12]. Bone and bone marrow viability can, therefore, be accurately assessed. This allows targeted treatment and is of prognostic value.

4D-CT Scanning

4D-CT is becoming increasingly used for the diagnosis and management of dynamic disorders in orthopedic surgery [13, 14, 15, 16, 17, 18]. 4D-CT scanning is created when a 3D-CT volume containing a moving structure is imaged over a period of time, creating a dynamic volume data set. Images can be acquired using a 320-multidetector CT scanner (Aquilion One, Toshiba Medical Systems, Inc., Toshiba-ken, Japan). The field of view (z-axis) includes the entire wrist. Table movement is not necessary as the gantry provides 16cm of z-axis volume using 0.5mm detectors. This compares to

traditional 64-slice CT scanners, which have only 4cm coverage. If the scanning table is kept still while scanning, then the objects up to 16cm in size can be moved and assessed over time. Post-processing allows the desired region of interest to be analyzed in 2D, 3D, or 4D. Routine protective garments worn by patient and examiner include eye protection, gowns, and lead gloves. Our wrist protocol includes six clinician-assisted active movements of flexion-extension, radial-ulnar deviation, clenched fist, dart-thrower’s, anti-dart-thrower’s, and prosupination. The forearm is supported in the scanner using a supportive strap to reduce artifact from the movement of the forearm and shoulder. The normal contralateral side is then compared to the symptomatic side. We compare the asymptomatic normal side to the pathological side. The patient has a “trial run” outside of the scanner until they are comfortable with movements and instructions. Settings are calibrated by the radiographer to minimize the radiation dose. We have performed 4D-CT scanning on a small series of Kienbock’s cases. Lunate position, morphology, overhang, and the nutcracker effect of the capitate can be assessed (Fig. 1 and 2). Dynamic instability due to rupture of the scapholunate or lunotriquetral ligaments can be diagnosed. We believe that the implementation of 4D technology will provide us with a better understanding of carpal kinematics in the Kienbock’s wrist.

Spect-ct

SPECT is a useful adjunct in the diagnostic workup of wrist pain, particularly when MRI, CT, or US prove inconclusive. Bone scans alone may provide greater specificity



Figure 3: Single-photon emission computed tomography (CT) scan of the wrist: A “hot spot” of intense osteoblastic activity is highly sensitive and specific for Kienbock’s disease (Copyright Dr. Gregory Bain).

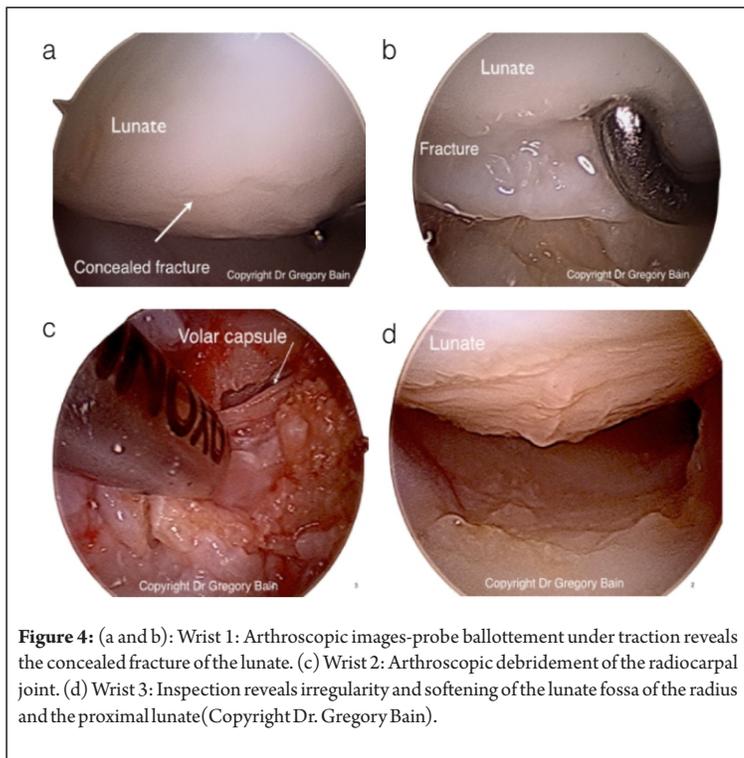


Figure 4: (a and b): Wrist 1: Arthroscopic images-probe ballottement under traction reveals the concealed fracture of the lunate. (c) Wrist 2: Arthroscopic debridement of the radiocarpal joint. (d) Wrist 3: Inspection reveals irregularity and softening of the lunate fossa of the radius and the proximal lunate(Copyright Dr. Gregory Bain).

but lower sensitivity compared with MRI in detection of osseous pathology. A bone scan combined with a CT scan, however, provides superior anatomical resolution and increased sensitivity with additional information on bone turnover [10]. Patients are administered with 800 MBq of Tc-99m HDP intravenously. Tc-99m HDP is renally cleared and has a half-life of 4–12 h. A three-phase bone scan consists of a dynamic blood flow image for the first 1–2 min, followed by static blood pool images in the following 4 min. At 2–4 h later, delayed static images are acquired. SPECT is then performed using two gamma cameras, followed by CT that provides an anatomical

tower and a 2.7mm 30° arthroscopes used. Portal sites and the radiocarpal joint are infiltrated with 15–20 mL of 1% lidocaine, 1:200,000 adrenaline mixture, and 20–30 min before the procedure. A tourniquet is applied to the arm but rarely inflated - only if bleeding impairs visualization. Standard portals used are 3–4, 6R, and MCR, MCU. Dry arthroscopy is then performed. This allows for better resolution of articular surfaces. Fluid insufflation compresses the capillaries within the joint and synovitis. As a result, tissue perfusion is better assessed dry[7,8]. Meticulous inspection and

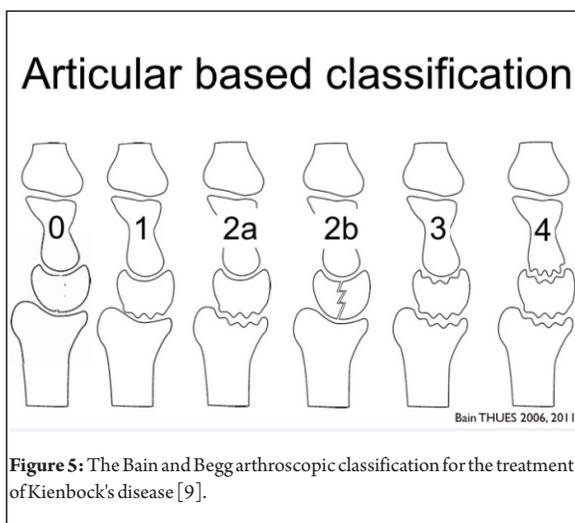


Figure 5: The Bain and Begg arthroscopic classification for the treatment of Kienbock's disease [9].

map of the attenuation. A “hot spot” of intense osteoblastic activity is highly sensitive and specific for KD (Fig. 3).

Wrist Arthroscopy in KD

We perform wrist arthroscopy for diagnostic purposes and treatment in all cases of KD. The arm is suspended with a traction

scaphoid flexes, and the attachment points become compromised. An arthroscopic shaver and Pituitary Rongeurs can be used to remove loose synovitis, chondral flaps, or necrotic bone (Fig. 4).

Bain and Begg Classification

The “functional” status of the articular surfaces and the wrist is graded using the Bain and Begg classification (Fig. 5) [19]. Articular surfaces are classified as the following;

- Functional - normal appearance, smooth, and glistening.
- Non-functional - degenerative changes including subchondral fracture.

Lichtman-Bain Algorithm

To create a framework for surgical management, we combined classifications to reflect the effect of KD on the vascular, chondral, and osseous state of the lunate and surrounding carpus [4, 6, 7]. By performing a thorough evaluation of the patient, then combining imaging and arthroscopic findings, the best treatment options available are presented to the surgeon. The ultimate choice of treatment depends on patient and surgical factors. This algorithm has been modified recently to reflect the importance of carpal instability in the pathogenesis of KD (Table 1)[8].

Individual Procedures Synovectomy and debridement

All cases we have assessed arthroscopically have varying degrees of synovitis. We use a full radius oscillating shaver to resect the synovitis and debride the joint. Loose chondral or osseous flaps are often present and can be removed with a shaver or Pituitary Rongeur. Arthroscopic grading can be performed once clear visualization is achieved. Arthroscopic debridement may be definitive treatment in mild cases in patients with low functional demands not suitable for more extensive procedures.

Arthroscopic Forage

A prerequisite for this procedure is functional surfaces throughout the carpus (Lichtman-Bain algorithm “B1”). KD can be conceptualized as a “compartment syndrome of bone [3].” Forage works by decompressing the lunate compartment.

tower and a 2.7mm 30° arthroscopes used. Portal sites and the radiocarpal joint are infiltrated with 15–20 mL of 1% lidocaine, 1:200,000 adrenaline mixture, and 20–30 min before the procedure. A tourniquet is applied to the arm but rarely inflated - only if bleeding impairs visualization. Standard portals used are 3–4, 6R, and MCR, MCU. Dry arthroscopy is then performed. This allows for better resolution of articular surfaces. Fluid insufflation compresses the capillaries within the joint and synovitis. As a result, tissue perfusion is better assessed dry[7,8]. Meticulous inspection and ballottement of the articular surfaces of the lunate and surrounding carpus then follows. Probe ballottement allows assessment of chondral integrity and the presence of a “floating” surface. A “floating” surface is created when a collapsed lunate is distracted on traction creating a potential space between the intact articular surface and the collapsed subchondral bone. A concealed fracture of the lunate articular surface can sometimes be identified(Fig. 4). The state of the perilunate ligaments is assessed, and often found to be torn as the lunate collapses,

The compromised section of lunate can be identified preoperatively on imaging. In some cases, the entire lunate is compromised. Viewing is through the 6R portal. The necrotic area is perforated with a drill through the 3–4 portal using arthroscopy and fluoroscopy as a guide. A weep hole is created, lowering venous hypertension within the bone. The guide can be left in position and morcellized autograft from the ipsilateral distal radius introduced into the defect and tamped to allow impaction.

Arthroscopic radioscapolunate (RSL) fusion

A prerequisite for this procedure is a functional midcarpal joint (“B1” or “C1a”). RSL fusions have historically suffered with a high non-union rate [20,21]. An arthroscopic approach is advantageous as it preserves the dorsal arterial capsular supply to the lunate. This may improve fusion rates although this has not yet been clinically proven. The procedure is as follows:

- We use the 4–5 or 6R portal for the scope with the burr in the 1–2 and 3–4 portals.
- The radial styloid and fossa are first debrided with a burr followed by the overhanging proximal scaphoid and lunate surfaces.
- Bone grafting or substitutes may be required to address any incongruity between the joints before screw placement.
- We use a 4.5-mm cannula through the 1–2 and 3–4 portals to pass the graft. A Foley catheter is usually placed in the 4–5 portal. The graft is then impacted.
- Under fluoroscopy:
 - An “RL” guide pin is introduced 1cm proximal to the dorsal rim of the radius and advanced percutaneously through

the central column of the distal radius to the lunate aiming at the volar horn. This maximizes lunate purchase; however, care is required not to injure the median nerve.

- An “RS” guide pin is passed from the radial column toward the proximal scaphoid at 45° on the AP view. On the lateral view, the pin is aimed along the midaxis of the radial styloid and proximal scaphoid.
- Cannulated compression screws are then advanced.

Arthroscopic scaphocapitate (SC) fusion

For this procedure, the articulations of the lunate are non-functional. The radiolunate and lunocapitate joints are bypassed with an SC fusion, and the load is redirected from the central to the radial column and through the scaphoid fossa. Therefore, the radioscapoid joint must be functional. This procedure is indicated in B3, C1a, C1b, and C2 disease.

- Introduce the scope in the MCU portal. Opposing surfaces of the capitate and scaphoid should be resected until bleeding bone occurs. If the lunate is fragmented, it should be excised.
- Reintroduce the scope through the 3–4 portal and ensure optimal alignment of the scaphoid and capitate before introducing hardware.
- Place the wrist in maximum extension and ulnar deviation to extend the scaphoid.
- Introduce the first wire through the 1–2 portal at the junction of the proximal and middle third scaphoid, 60° to the coronal plane of the wrist and aiming to the middle of the scaphoid and capitate.
- Introduce the second wire 5mm distal to the first and parallel to it.

- Cannulated screws are then advanced over the wires and checked.

Arthroscopic proximal row carpectomy

The lunate fossa and proximal capitate should be functional (B2 or B3 disease).

- An initial arthroscopic assessment and debridement are performed.
- The central portions of the lunate, scaphoid, and triquetrum are excised first. The distal one-third of the scaphoid can be retained for the attachment of the STT and dorsal intercarpal ligaments.
- Care should be taken to avoid the radial artery.
- Irrigation should be used to avoid overheating.
- Bipolar cautery is used to release capsular attachments.

Conclusion

Despite recent developments in the understanding of the etiology and pathogenesis of KD, diagnosis and management can still prove challenging [3]. Innovations in imaging techniques are improving our understanding of the disease process; its effect on the lunate and the surrounding carpus. Our modified algorithm provides a framework for the treating surgeon. It is not intended to be all-encompassing but provides a series of options for each stage of the disease. It is the senior author’s view that arthroscopy is a vital tool in the assessment and management of these patients. As well as being the “gold standard” for the assessment of the chondral surfaces, it has vastly improved our understanding of the KD process over the last 20 years. It also allows for minimally invasive surgical treatment.

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