Review Article

Osteonecrosis of the Lunate: Kienböck Disease

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Abstract

Kienböck disease, osteonecrosis of the lunate, is a well-known but poorly understood complication seen by hand surgeons. This review presents the background and important patient-specific parameters of the disease and reviews the numerous treatment options that exist for the disease.

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Neither of the following authors nor any immediate family member has received anything of value from or has stock or stock options held in a commercial company or institution related directly or indirectly to the subject of this article: Dr. Rioux-Forker and Dr. Shin.

Supplemental digital content is available for this article. Direct URL citation appears in the printed text and is provided in the HTML and PDF versions of this article on the journal's Web site (www.jaaos.org).

This review article discusses the history, etiology, and course of Kienböck disease and reviews the literature on both the diagnosis and management of this relatively infrequent carpal pathology.

J Am Acad Orthop Surg 2020;28: 570-584

DOI: 10.5435/JAAOS-D-20-00020

The first description of Kienböck disease, also known as osteonecrosis of the lunate, is attributed to Peste in 1843. However, his case report is an autopsy, is on a patient dying from a five-story fall, and is most consistent with a traumatic lunate fracture rather than osteonecrosis and carpal collapse. In 1910, Robert Kienböck, a radiologist, described the radiographic changes associated with lunatomalacia, and his name has become the eponym for lunate osteonecrosis.

The exact mechanism(s) of Kienböck disease has not been fully elucidated. It is thought to be an interplay between altered vascular perfusion, repetitive microtrauma, variable lunate anatomy, altered loading and kinematics, and potential systemic disease.

Relevant Anatomy

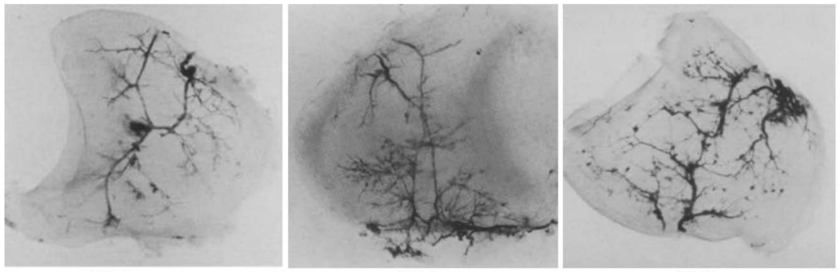
Lunate ischemia is thought to be a major factor in Kienböck disease. Although the lunate typically has both palmar and dorsal blood supplies, 20% to 26% of lunates may have a singular palmar blood supply, increasing their risk for osteonecrosis.[1,2] A singular palmar blood supply and type I intraosseous pattern may predispose a lunate to osteonecrosis from vascular disruption or coronal fracture. A dual dorsal blood supply and intraosseous plexus (pattern Y or X) could be protective of osteonecrosis (Figure 1).

Lunate biomechanics and altered loading have been suggested as additional factors in Kienböck disease. Schuind et al[3] estimated the relative force transmissions across the radioscaphoid (RS) joint, the radiolunate (RL) joint, and the triangular fibrocartilage complex to be 55%, 35%, and 10%, respectively. They reported an increased lunate uncovering index (degree to which the lunate extends ulnar to the distal radius) resulted in a less force transmission across the radiolunate joint with higher transmission across the radioscaphoid and ulnolunate (UL) joints.[3] Conversely, Ledouc reported lunate uncovering increased RL peak pressures but without a notable change in RL/UL load ratios.[4] Ulnar negative variance also increased RL/UL load ratios and peak pressure ratios.

Vagaries in lunate morphology may also contribute to Kienböck disease. Viegas et al[5] characterized lunate morphology based on the absence (type I) or presence (type II) of a medial hamate facet (Figure 2). A type II lunate provides inherent carpal stability.[6] In the setting of Kienböck disease, this stability provides some protection against coronal fracture and advanced progression of Kienböck disease.[7]

Proximal capitate morphology has been considered in relation to Kienböck disease as well. Yazaki et al[8] described three different capitate morphologies: flat type (64%), spherical (21%), and V-shaped (14%) (Figure 2). There were no V-shaped capitates associated with type I lunates, whereas both flat and spherical capitates were seen with both type I and II lunates. They postulated that the V-shaped capitate may increase loading on the radial lunate and be a risk factor.

Figure 1



Photograph showing the lunate vascularity patterns. An intraosseous plexus (type Y and X) may be protective of lunate osteonecrosis when compared with the I type. (Reproduced with permission from Gelberman RH, Bauman TD, Menon J, Akeson WH: The vascularity of the lunate bone and Kienbock's disease. *J Hand Surg* 1980;5[3]:272-278, with permission from Elsevier.)[1]

Natural History

A classic patient with Kienböck is a young man (20 to 40), a manual laborer, with unilateral disease. Patients present with nonspecific symptoms including generalized central wrist pain, altered ROM, and pain with grip, loading, and decreased ROM. Most report an insidious onset with progressive symptoms without a traumatic event.

Limited studies and knowledge exist on the natural history of Kienböck disease. Keith et al[9] reported a series of 33 patients managed conservatively and reviewed the course of their disease. They reported that increasing stages of disease resulted in no change in visual analog pain scores or HSS scoring, but they did report a trend of decreasing ROM, grip strength (40% difference between Lichtman stage II and IV), and deteriorating DASH scores, worse in patients with symptoms over 10 years. They also found that the radioscaphoid angle was the best measurement to characterize the radiologic progression of the disease and progressive carpal collapse.

Conversely, Fujisawa et al[10] reported favorable results with conservative management in their case series of 17 patients with over 10 years of follow-up. All patients reported moderate to severe pain at their initial visit, but at the final follow-up, nine were pain-free, six had slight discomfort during or after heavy work, one had occasional moderate pain, but none had severe pain stopping them from working with improved pain. Only one patient had a flexion-extension arc under 60°. The mean grip strength was 79.9% of contralateral (range 30% to 100%).

Radiologically, five patients had no progression, eight progressed, and four improved; however, initial true lateral radiographs were not available for most patients.

Diagnosis

Diagnosis is made by correlating physical examination, history, and radiographic findings (XR, including ulnar variance views). Radiographically, Kienböck disease starts with osteonecrosis changes in the lunate including sclerosis and MRI signal changes. Further degeneration results in lunate collapse, fracture, scaphoid flexion, loss of carpal height parameters, and carpal arthritis including the radiolunate, capitolunate, and possibly radioscaphoid joints.

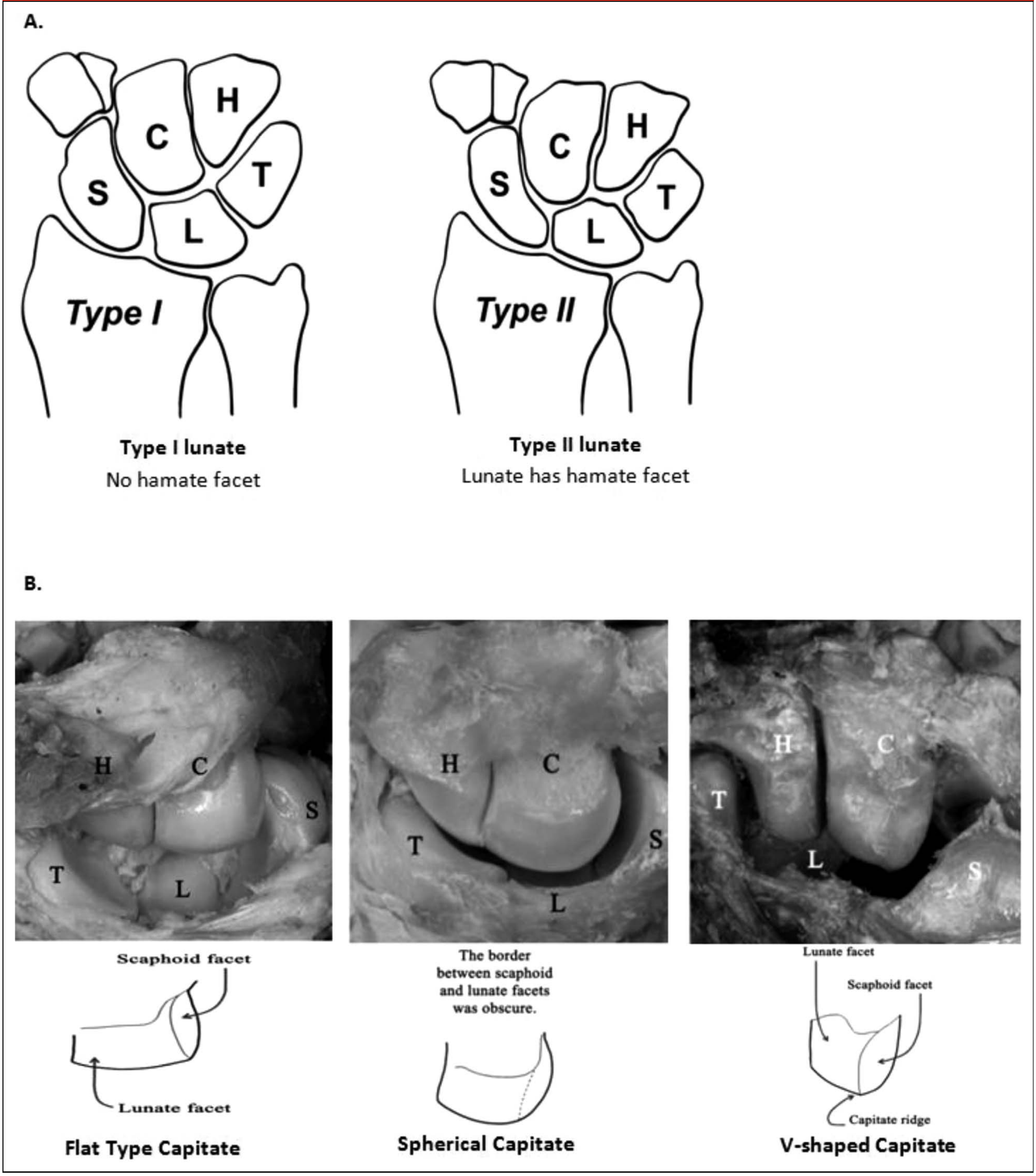
Advanced imaging is helpful because CT scans frequently result in upstaging in Kienböck disease, especially in stage II patients with lunate collapse not seen on plain radiographs. MRI scans facilitate the diagnosis of osteonecrosis in patients who have no other radiographic changes. Gadolinium-enhanced MRI scans may improve diagnostic accuracy. Although CT and MRI characterize the osseous architecture and soft-tissue pathology, diagnostic wrist arthroscopy is essential for accurate evaluation of the articular surfaces because advanced imaging does not accurately reflect cartilaginous degradation (Figure 3).

Classification Systems

Staging is based on the Lichtman classification describing the degeneration and changes seen within the lunate and carpus (Figure 4).[11,12] The classification differentiates early findings from unstable and nonsalvageable lunates and end-stage pan-lunate arthritis. The Bain arthroscopic grading system describes the status of the intermediate column articular surfaces and thus guides the treatment (Figure 5).[13]

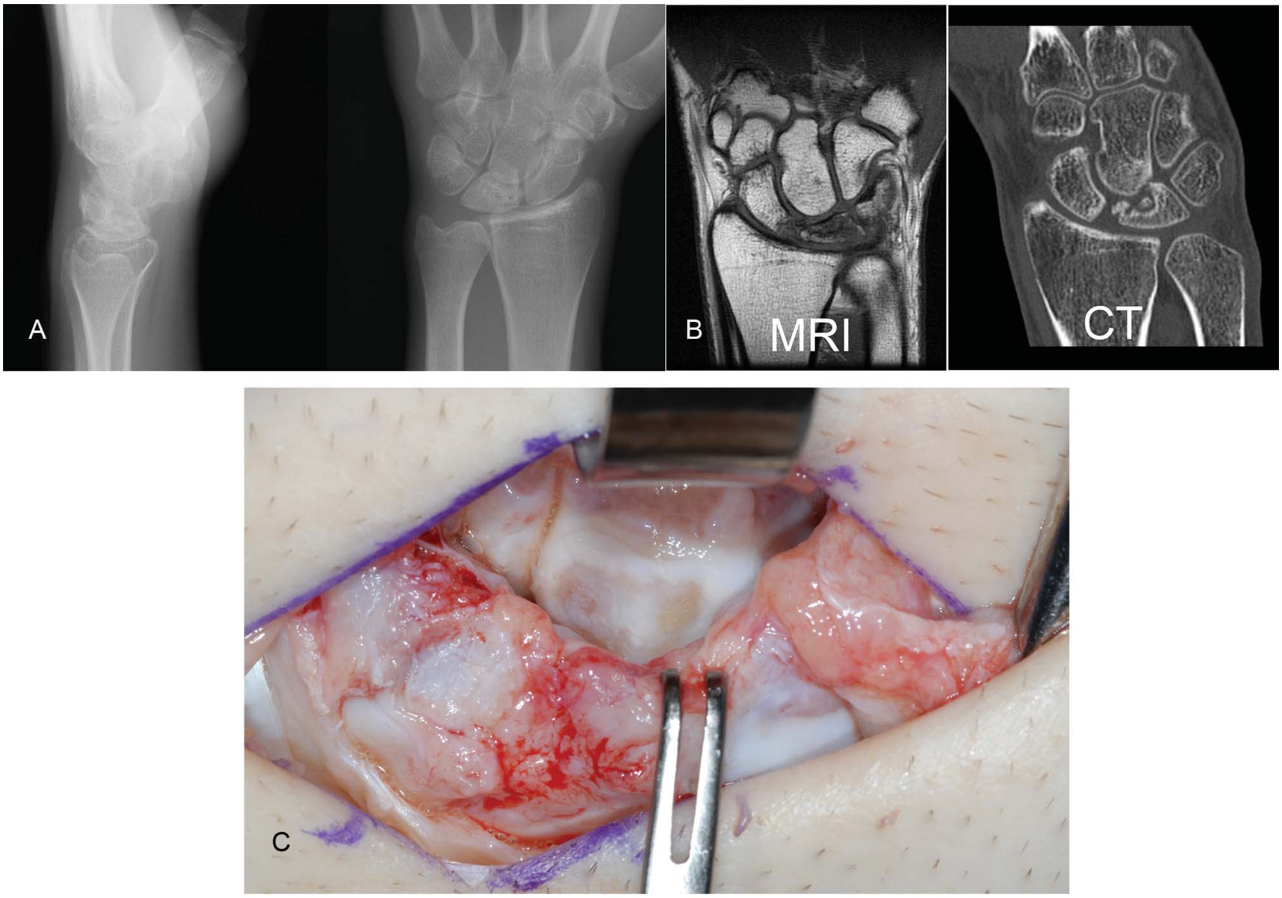
More recently, an unvalidated, combined classification system has been introduced (Figure 6),[14] which accounts for the osseous, vascular, and cartilaginous effects of the disease while adding patient age and secondary wrist involvement with management options for each stage.

Figure 2



Photograph showing the carpal morphologies. A type II lunate with a hamate facet and articulation helps prevent carpal collapse, lunate coronal fracture, and progression of Kienböck disease. There is some thought that a V-shaped capitate, when compared with the flat type and spherical type, may result in increased loading across the lunate and microtrauma, which may contribute to the development of osteonecrosis. (Reproduced with permission from Haase SC, Berger RA, Shin AY: Association between lunate morphology and carpal collapse patterns in scaphoid nonunions, *J Hand Surg* 2007;32 [7]:1009-1012, and Yazaki N, Burns ST, Morris RP, et al: Variations of capitate morphology in the wrist. *J Hand Surg* 2008;33(5):660-666, with permission from Elsevier.)[6,8]

Figure 3



Photographs showing the case series showing that preoperative imaging (XR, CT, or MRI) does not capture the state of articular cartilage. Intraoperatively, this patient was found to have a denuded proximal lunate articular surface (Reproduced with permission from Mayo Foundation for Medical Education and Research, Rochester, MN. All rights reserved.)

Treatment

Conservative Management

The early conservative management of Kienböck disease includes immobilization and anti-inflammatory medications. The rationale for conservative treatment is based on the report by Stahl that 50% of patients improved or were cured after two months of immobilization.[15]

Newer studies have shown that conservative management is indicated in early stage findings (Lichtman stage 1 or 2 and Bain 0) and provides symptom relief and may improve synovitis but may not change the progression of the disease. Keith et al[9] outlined a predictable pattern of deteriorating motion, grip strength, and DASH scores in these patients.

Surgical Management

Treatment options for Kienböck disease fall into four main categories: core decompression, joint leveling/lunate unloading, lunate revascularization, and salvage procedures. Given the relative rarity of the disease, the variable patient anatomy and Lichtman stages/Bain grades, few high-quality well-controlled studies exist to help guide treatment. It is imperative to consider a patient's anatomy, the degree/locations of articular involvement, and risk factors when determining the treatment of patients with Kienböck disease.

Core Decompression

Core decompression was first described by Illarramendi et al[16] in 2001. Core decompression involves surgical impaction of the cancellous bone within the metaphysis of the distal radius through a cortical window. They reported 22 patients with stage I-IIIa Kienböck disease with an average of 10 years of follow-up and reported good results, with 16 of 22 pain-free patients, with an average range of motion (ROM) and grip strength of 77% and 75% of the

Figure 4

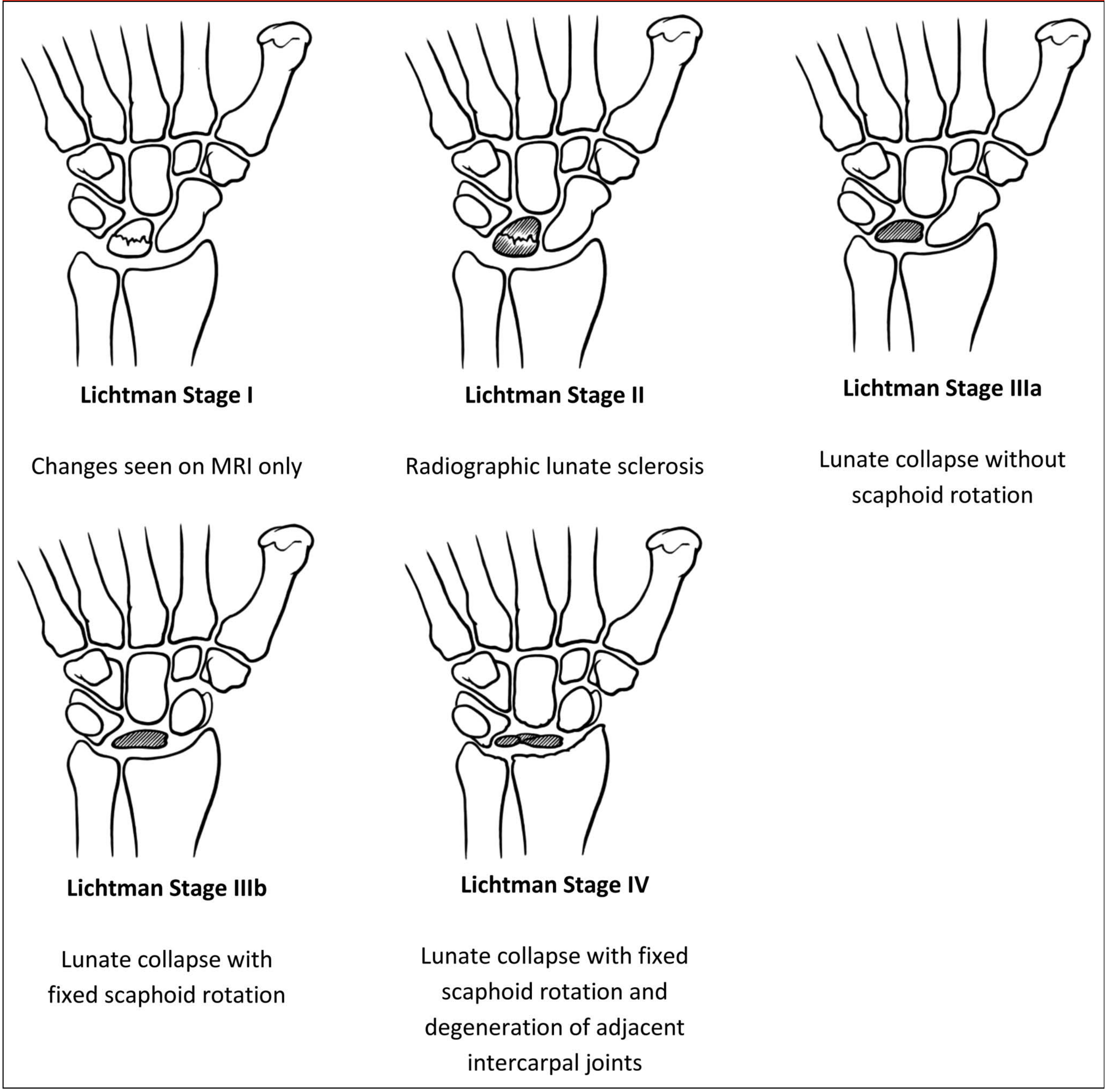


Illustration showing the modified Lichtman classification. (Reproduced with permission from Mayo Foundation for Medical Education and Research, Rochester, MN. All rights reserved.)[11,12]

contralateral side. Seventeen of 22 patients had no change in the Lichtman stage; two improved radiologically, whereas three progressed radiologically. Based on T1/T2 MRI signal change, some lunate revascularization may be occurring. Sherman et al[17] evaluated core decompression in a biomechanical cadaver model and found that the stiffness of the distal radius markedly decreased (198.6 N/mm from 229.4 N/mm) without much change across the lunate fossa. Zaidenberg et al[18] reviewed their 10+ year results of core decompression of the distal radius in the Lichtman stage II and IIIa patients. They reported favorable modified Mayo Wrist Scores, 9 of 23 excellent scores, 11 of 23 good scores, 2 of 23 moderate, 1 of 23 poor, and an average visual analog scale (VAS) pain score of 1.1. No notable outcome difference was observed in stage

Figure 5

Grade	Description	Recommended Treatment
Grade 0 	All articular surfaces are functional	Synovectomy Joint leveling Vascularised bone graft Forage
Grade 1 	One nonfunctional surface. Usually the proximal lunate	RSL Fusion PRC
Grade 2a 	Two nonfunctional surfaces. Proximal lunate and lunate facet of radius	RSL Fusion
Grade 2b 	Two nonfunctional surfaces. Proximal and distal surfaces of the lunate	PRC Lunate replacement
Grade 3 	Three nonfunctional surfaces. Likely to be a preserved capitate articular surface	Hemiarthroplasty Total wrist fusion Wrist replacement
Grade 4 	Four nonfunctional articular surfaces.	Total wrist fusion

Synovectomy is performed in all patients at the time of arthroscopy.

PRC indicates proximal row carpectomy; RSL fusion, radioscapholunate fusion.

Illustration showing the Bain arthroscopic grading system. (Reproduced with permission from: Bain G, Begg M: Arthroscopic assessment and classification of Kienbock's disease in Techniques. *Tech Hand Up Extrem Surg* 2006;10[1]:8-13 and Bain G and Durrant A: An articular-based approach to Kienbock osteonecrosis of the lunate. *Tech Hand Up Extrem Surg* 2011;15[1], with permission from Wolters Kluwer Health, Inc.)[13]

Figure 6

A. Patient's age?

A1. < 15 years – Non-operative
A2. 16 -20 years – Non-operative first. Consider unloading procedure.
A3. > 70 years – Non-operative first. Consider synovectomy and / or follow algorithm below.

B. Stage of the lunate?

B1. Lunate intact - Protect / unload the lunate
(Cortex and cartilage intact – Lichtman 0, I, II, Schmitt A, Bain 0)
Orthosis or cast first (trial for 2–3 months)
Radial shortening osteotomy, capitate shortening for ulnar +ve (radial epiphysiodesis*)
(Alternatives – Lunate decompression, vascularized bone graft*, radius forage*)

B2. Lunate compromised - Consider lunate reconstruction
(Localized lunate disease – Lichtman IIIA, Schmitt B, Bain 1)
Lunate reconstruction: MFT*, lunate replacement*, PRC (RSL fusion, SC [or STT] fusion)

B3. Lunate not reconstructable - Lunate salvage
(Advanced lunate disease - Lichtman IIIC, Schmitt C, Bain 2b)
Lunate salvage (excision): Lunate replacement*, capitate lengthening, PRC (SC fusion)

C. State of the wrist?

C1. Carpal instability with intact articulations - Stabilize
Typical scaphoid flexion, with RSA > 60 degrees (Lichtman IIIB).
Stabilize radial column (SC fusion)

C2. Localized carpal degeneration - Reconstruct

C2a. Radiolunate articulation compromised (Lichtman IIIA, Bain 2a)
Bypass (SC fusion), reconstruct (MFT graft) or replace (lunate prosthesis), Fuse (RSL fusion)

C2b. Radioscaphoid articulation compromised
PRC if lunate facet intact, RSL fusion if lunate facet compromised and midcarpal joint intact.

C3. KDAC, Advanced carpal collapse and degeneration - Salvage
Wrist not reconstructable (advanced wrist disease – Lichtman IV, Bain 4)
Salvage (fusion or arthroplasty).

Other options that can be considered have been placed in (parentheses). STT fusion is an alternative to SC fusion.
*Alternate procedures, techniques that require specialized skills and therefore affect what the surgeon can offer.
The classification determines the recommended treatment based on the patient's age (A), status of the lunate (B) and the status of the wrist (C). What the surgeon can offer (D) and what the patient wants (E) ultimately determine what is performed.

Illustration showing updated, unvalidated Bain/Lichtman combined classification system. (Reproduced with permission from © Georg Thieme Verlag KG.)[14]

II versus IIIB patients, and 4 of 23 patients had radiologic progression of their disease.

Mehrpour et al[19] have recently introduced the idea of dorsal lunate core decompression. They reported 5-year outcomes on 20 patients (Lichtman stage I-10 patients, II-6 patients, IIIa-3 patients, and IIIb-1 patient) and found improved mean VAS, 88 to 14, and DASH scores from 84 to 14. Two patients, with stage IIIa and IIIb disease, required additional surgery (radial shortening).

Joint Leveling/Lunate Unloading

Joint leveling/lunate unloading procedures alter the biomechanics of load transmission across the wrist and lunate by equalizing the radial and ulnar variance or by shortening carpal bones. This includes radial shortening, capitate shortening, and the Graner procedure. Horii et al evaluated the force transmission in a carpal mathematical model and found that STT, scaphocapitate arthrodesis (SC), and CH arthrodesis had minimal effects in radiolunate loading (94%, 88%, and 105% of normal radiolunate loading force, respectively), whereas 4-mm joint leveling procedures (radial shortening or ulnar lengthening) and capitate shortening provided far more unloading at the radiolunate joint (48% and 34% of normal loading force, respectively). In this model, the capitate shortening dramatically increased loading at the scaphotrapezial and triquetral-hamate joints.[20]

Radial Shortening Osteotomy

Radial shortening osteotomy (RSO) unloads the lunate, particularly in the negative ulnar variance wrist. Koh et al[21] reviewed their outcomes of RSO in one Lichtman stage I, four stage II, 11 stage IIIa, and six stage IIIb wrists. A standard RSO was performed for those with ulnar negative variance, and a closing wedge osteotomy was performed for those with ulnar neutral or positive variance. They found notable improvement in ROM (from 67% to 87% of contralateral wrist), grip strength (from 62% to 85% of contralateral wrist), pain (12 pain-free and 12 with mild pain), and anecdotal signs of lunate healing (improved cysts and sclerosis). The Lichtman stages were improved in two patients, unchanged in 11, and worsened in nine. The Mayo Wrist Scores were good or excellent in 96% of patients.

Zenzai et al[22] found similar results in a long-term follow-up of 13 to 25 years in 14 wrists treated with RSO. They performed a RSO for ulnar minus and neutral variance patients and a RSO combined with an ulnar shortening osteotomy for those with ulnar positive variance. Pain scores, grip strength, ROM, and Mayo Wrist Scores were statistically improved, whereas three patients advanced in stage and six patients developed worsening midcarpal and distal radioulnar joint arthritis.

Wada et al[23] reviewed their 10 year follow-up results in 13 patients (two stage 2, eight stage IIIa, and three stage IIIb) with ulnar neutral or position variance managed with a distal radius closing wedge osteotomy. They found statistically significant improvements in pain (three painless and 10 mild pain with some activity), grip (98%), and ROM (83%) compared with the contralateral wrists. However, 8 of the 13 patients progressed radiographically. There were also changes in carpal alignment, including a radial shift of the carpus, decreased radial inclination, and an increased lunate covering ratio.

Capitate Shortening

Capitate shortening or partial capitate shortening is an option in ulnar neutral or positive patients. Gay et al[24] performed a review of 11 ulnar neutral patients who had a capitate shortening for stage II (five) and stage IIIa (six) Kienböck disease with a mean follow-up of 67 months. They found good pain improvement (mean VAS improved from 6 to 1.7), with seven patients who were pain-free, two with intermittent pain, and two without relief (VAS five and seven). Strength improved from 47% to 72% of contralateral wrist, but there was no change in ROM (69.7% to 66.4%).

Radiographically, six patients had no Lichtman stage progression, three improved, and two worsened.

No notable change was observed in carpal height parameters, but scaphoid flexion was not evaluated.

Partial capitate shortening has been described because of the concerns of altered carpal kinematics leading to palmar flexion of the scaphoid, persistent lunate loading, and carpal collapse.[25] This technique preserves the capitotrapezoid and capitoscaphoid articulations and the capitates radial length while shortening the lunate loading portion of the capitate. Limited clinical results are available to date. Singer et al[26] reported a series of 20 patients (nine stage II and 11 stage IIIb) managed with partial capitate shortening, with an average follow-up of 36.5 months. They found a modest improvements in ROM (flexion/extension arc 57% to 65.5%), grip (49% to 63%), VAS (6.9 to 3.3), and quick DASH score (60.8 to 38.3), with Lichtman II patients obtaining better outcomes.

Modified Graner Procedure

The modified Graner procedure is indicated for patients with relative sparing of the lunate facet and proximal capitate. The lunate is excised, and a transverse osteotomy is made in the capitate body. The proximal pole of the capitate is translated proximally to replace the lunate, and the osteotomy site and midcarpal surfaces are arthrodesed. Takase and Imakiire reported a case series of 15 patients with an average age of 39 with an average of 6.5 years of follow-up.[27] They reported that grip strength returned to 80% of the contralateral wrist at 1 year, and the wrist range of motion was unchanged preoperatively (74° flexion/extension). They had only two patients with pain with activity, but no conversions to total wrist arthrodesis. More recently, Ruettermann in a level 5 article cautioned against the modified Graner procedure, cited that many of its original advocates have abandoned the technique because of poor outcomes.[28]

Lunate Revascularization

The concept of introducing a new vascular supply with vascular bundles or vascularized bone grafts (VBG) has resulted in numerous options over the past two decades. Pedicled VBGs often used in Kienböck disease include those from the metacarpal bases, dorsal, or palmar distal radius. Free vascularized flaps have also been used, including the medial femoral condyle, medial femoral trochlea (MFT), and iliac crest.[29]

Revascularization is only a viable option if the lunate is salvageable. Historically, Lichtman stage IIIb was a contraindication to revascularization, but recent advances have shown the Bain grade to be a better predictor because the condition of the cartilage shell of the lunate is the primary determining factor. A lunate with an intact cartilaginous shell or a fractured lunate that is amenable to screw fixation without marked arthritic change can be salvaged.[30]

The Mayo Clinic group described their experience with the dorsal 4 + 5 extensor compartment artery (ECA) pedicled VBG in 26 patients with stage II (12), stage IIIa (10), and stage IIIb (four) Kienböck disease with a mean follow-up of 31 months (Figure 7).[30] They found improvements in ROM (flexion-extension from 68% to 71%), grip strength (50% to 89%), an average Mayo Wrist Score of 77, with excellent results in six, good results in six, fair results in nine, and poor results in three. Ninety-two percent had pain improvement. Satisfactory Lichtman outcome scores were seen in 85%, 77% had no further collapse, and 71% had evidence of revascularization. Those who had the signs of revascularization on MRI had higher Mayo Wrist Scores, more frequently returned to work, and were less likely to worsen radiologically.

Fujiwara et al[31] reviewed their experience with vascularized bone grafting in stage III Kienböck with a mean follow-up of 12 years. They had 18 cases (10 stage IIIa AND 8 stage IIIb) treated with VBGs from the third metacarpal (9), second metacarpal (2), and dorsal distal radius VBG, two to three intercompartment supraretinacular (4), and one to two intercompartment supraretinacular (3). Of these patients, five stage IIIb patients had concomitant RSO and two stage IIIb patients had concomitant capitate shortening (neutral ulnar variance). According to the Mayo Wrist Scores, the postoperative results were categorized as excellent (eight patients), good (seven), and fair (three). Wrist flexion improved by 18% and 17%, extension by 8% and 18%, and grip strength by 53% and 59% in stage IIIa and IIIb patients, respectively. Two patients had radiologic disease progression; none had radiologic Lichtman Stage improvement. Both stage IIIb patients with concomitant RSO had improved carpal height and Stahl index scores.

Lunate salvage has been performed in stage II-IIIa/b patients with notable arthritic change or fragmentation limited to the proximal pole of the lunate with the MFT free flap (Bain grade 1 or 2B). For this limited patient demographic, a free vascularized osteochondral graft can be used to reconstruct the proximal lunate. Bürger et al reported a case series of 16 patients with a mean age of 35 years with stage II, IIIa, and b Kienböck treated with a free MFT osteochondral graft. They found perseveration of preoperative range of motion, grip strength of 85% of contralateral side, and complete pain relief in 12 of 16 with a minimum 1 year of follow-up. They also had radiographic down grading in four patients (IIIa/b to II).[32]

Wrist Salvage

As Kienböck disease progresses, the lunate fragments and the scaphoid develops a fixed flexion stance with proximal migration of the capitate. Subsequent and advancing arthritic changes occur across the radiolunate and capitolunate joints. When the lunate is no longer salvageable (too fragmented with arthritic adjacent articular surfaces), a number of treatment options exist. These salvage procedures include proximal row carpectomy (PRC), limited wrist arthrodesis, and total wrist arthrodesis. The most common limited wrist arthrodesis options for Kienböck disease include radioscapholunate arthrodesis (RSL), SC, and scaphotrapeziotrapazoid (STT) arthrodesis.

PRC is the creation of a nonanatomic radiocapitate articulation by removal of the proximal row. There is a risk in PRC of progressive arthritis and the future need for a total wrist arthrodesis. Thus, alternative treatments are frequently sought in younger patients. Croog and Stern reviewed their experience with PRC in advanced Kienböck disease Lichtman stages III (18 patients) and IV (three patients) with an average follow-up

Figure 7

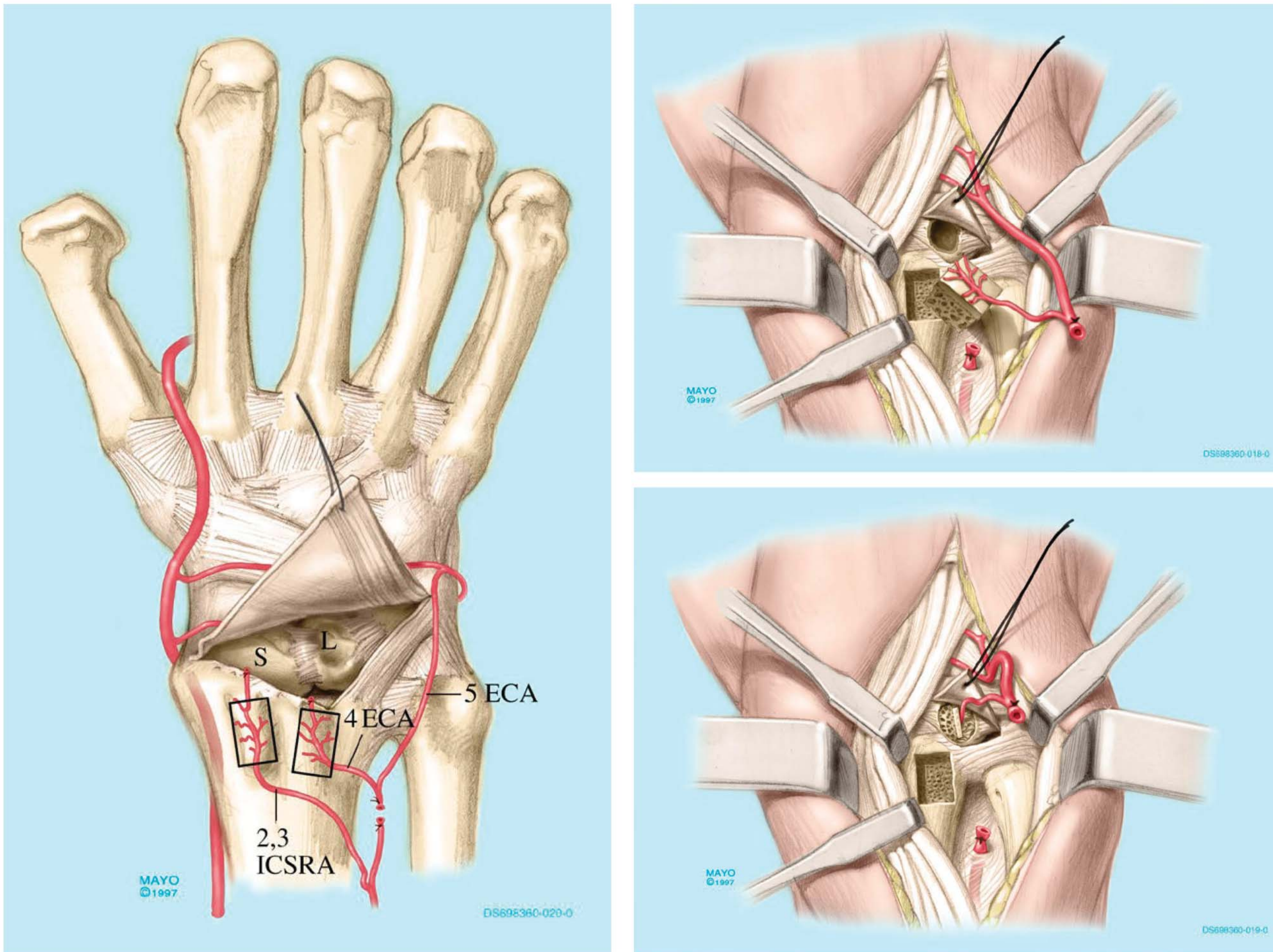


Illustration showing four to five extensor compartmental artery vascularized bone graft. (Reproduced with permission from Mayo Foundation for Medical Education and Research, Rochester, MN. All rights reserved.)

of 10 years.[33] The average patient age at the time of operation was 38, and seven patients were heavy laborers. Their patients did well overall, with an average flexion-extension arc of 78% of the contralateral wrist (105°), 110% of the preoperative ROM, 87% of the contralateral grip strength, and an average modified Mayo Wrist Score of 84. Radiographic follow-up showed degeneration of the radiocapitate joint in 87%, which did not correlate with the subjective symptoms. Seven were pain-free, nine had mild pain, and two had moderate pain. Three failed PRC, two of whom had stage IV disease at the time of initial PRC and went on to radiocapitate fusion.

Chim and Moran performed a systematic literature review of the long-term (10+ years) outcomes of PRC.[34] They identified 135 patients from six studies, with 33% of the patients having Kienböck disease. They reported a postoperative mean flexion-extension arc of 73.5° and grip strength of 68.4% of contralateral side, with DASH, PRWE, and the Mayo Wrist scores of 21.5, 28.7, and 66.9, respectively. They found that 79% of patients had radiocapitate arthritis, but this did not correlate with symptoms, outcome measures, or time from PRC. They did express concerns that a PRC may be a poor option in a laborer because of decreased grip strength and concerns of progressive arthritis and failure.

The RSL arthrodesis is indicated in patients with a nonsalvageable lunate, ongoing radiolunate, and radioscaphoid arthritis, but sparing of the midcarpal joints (specifically the capitolunate). McGuire and Bain reviewed their RSL arthrodesis outcomes, with and without excision of the distal pole of the scaphoid.[35] Without excision of the distal pole of the scaphoid, nonunion rates between 0% and 25% and wrist range of motion between 33%

Table 1

Kienbock Quick Reference Table

Treatment Options	Description	Indication	Pro	Con	Outcomes	References
Conservative management	Immobilization, anti-inflammatories	Lichtman stage 1-2, Bain 0	Low risk. Synovitis may improve. Avoid surgical complications. Preserve surgical options. Some studies indicate Kienböck disease may burn out.	Likelihood of further disease progression and worsening symptoms warranting surgical intervention.	Inconsistent results among studies. Some report good symptom improvement or resolution, whereas others report predictable decline both clinically and radiographically.	9,10,15
Core decompression	Surgical impaction of native cancellous bone within the distal radius metaphysis. Alternatively impaction of the cancellous bone within the lunate.	Lichtman stage I-IIIa with limited articular involvement or symptoms	Simple procedure. Relatively low risk. Limited complication profile.	Mechanism of improvement not well understood. Likely does not directly alter ongoing pathology. Is not as definitive as other options. Limited lunate unloading.	16 of 22 pain-free, grip strength and ROM 75% and 77% of contralateral. 9 of 23 excellent Mayo Wrist Scores, 2 of 23 moderate, 1 of 23 poor. Average VAS 1.1. Lunate core decompression: VAS 14 of 100, DASH scores ranging from 14 to 84.	16-19
Radial shortening osteotomy	Excision of a wafer of distal radial diaphysis to effectively shorten the radius relative to the ulna by a precalculated amount.	Typically, ulnar negative patients with lower grade disease (Lichtman stage I-IIIa) and minimal articular involvement/ symptoms. Some have stretched the indication to include stage IIIb or ulnar neutral or even ulnar positive patients (with a closing wedge osteotomy).	Provides some lunate unloading. Relatively simple procedure. Widely performed. Numerous studies with long-term follow-up show reliability.	Limited lunate offloading. Risk profile is a bit higher, and includes nonunion.	ROM 87% (from 67%), grip strength 85% (from 62%), 12 of 22 pain-free, 12 of 22 mild pain. Good or excellent Mayo Wrist Scores in 96%. Statistically significant improvements in grip strength (98%), ROM (83%), and pain (3 painless, 10 mild pain with activity).	20-23
Capitate shortening	Transverse wafer excision in the capitate vs partial capitate shortening, preserving the radial length of the capitate.	Lichtman stage I-IIIa, limited articular involvement or symptoms. Some have used in the Lichtman stage IIIb.	Directly unloads the lunate. Can be done in ulnar neutral or positive patients.	Risk profile includes capitate nonunion, capitate proximal pole osteonecrosis, advancing carpal collapse, worsened capitotrapezoid, capitoscaphoid, or midcarpal arthritis. Studies of the long-term results are limited.	Capitate shortening: VAS pain score 1.7 (6). Grip strength 72% (47%). No change in ROM (69.7%). Partial capitate shortening: ROM 65.5% (from 57%), grip strength 63% (from 49%), VAS 33.3 (from 6.9), with a quick DASH score improvement (38.3 from 60.8)	

(*continued*)

MFT = medial femoral trochlea

Table 1 (*continued*)

Kienbock Quick Reference Table

Treatment Options	Description	Indication	Pro	Con	Outcomes	References
Modified Graner	Lunate excision, transverse capitate osteotomy, proximal translation of the capitate proximal pole and midcarpal arthrodesis.	Any Lichtman stage with relative cartilage sparing of the lunate fossa and proximal pole of the capitate.	Allows replacement of a fragmented and degenerated lunate. Can obtain a new, radiocapitate articulation and preserve carpal height. Mechanically similar to a four-corner fusion and thus, in theory, makes sense for younger high-demand hands.	Limited long-term studies. Many of its early advocates have abandoned the technique because of poor outcomes in their patients. Risks include nonunion, osteonecrosis of the proximal pole of the capitate, radiocapitate arthritis.	Grip strength improvement to 80% of contralateral at 1 year, unchanged ROM over 6.5 years, only 2 of 15 patients with pain with activity, and no conversion to total wrist arthrodesis in one study.	27,28
Lunate revascularization	Pedicled or free vascularized bone graft to the lunate.	Historically, the Lichtman stage I-IIIA, but more recently some have revascularized stage IIIb Kienböck with MTF free flaps. Relative sparing of the perilunate articular cartilage.	Provides direct robust blood flow and healthy bone to a devascularized, osteonecrotic lunate. Can help decrease carpal collapse. Can allow replacement of the proximal lunate cartilage (free MFT). Can be a last resort before salvage procedures.	Technically challenging, does not replace cartilage loss (except MFT), limited long-term follow-up studies.	Improved ROM (71% from 68%), grip strength (89% from 50%), with excellent Mayo Wrist Scores in 6 of 26, good in 6 of 26, fair in 9 of 26, and poor in 3 of 26. Improved ROM (26% to 35% improvement), grip strength (53% to 59% improvement). Patients with MFT had preservation of preoperative ROM, grip strength of 85% of contralateral side, and 12 of 16 patients had complete pain relief.	29-32
Proximal row carpectomy	Excision of the scaphoid, lunate, and triquetrum, creating a new radiocarpal articulation, with the radiocapitate joint at the primary load-bearing joint.	Advanced Kienböck disease with relative sparing of the cartilage at the lunate fossa and proximal capitate.	Relatively simple procedure. Commonly used for various wrist pathologies and arthritis. Well-studied outcomes and risk profile across various diseases.	Limited to a specific patient subset (does not address proximal capitate or lunate fossa arthritis). Risk of progressive arthritis at the nonanatomic new radiocarpal joint. Salvage would be total wrist fusion.	Good preservation of motion (ROM 78% of contralateral, 110% of preoperative ROM), 87% of contralateral grip strength, average Mayo Wrist Score of 84, at 10+ years 7 of 21 patients were pain-free, 9 of 21 mild pain, 2 of 21 moderate pain, 3 of 21 went on to total wrist fusion. Mean flexion-extension arc of 73.5%, grip strength of 68.4% of contralateral, Mayo Wrist Scores of 66.9	33,34

(*continued*)

MFT = medial femoral trochlea

Table 1 (*continued*)

Kienbock Quick Reference Table

Treatment Options	Description	Indication	Pro	Con	Outcomes	References
Radioscapholunate arthrodesis	Arthrodesis of the radiocarpal joint, specifically between the radioscapholunate articulations.	Any Lichtman stage with relative cartilage sparing of the capitolunate joint, but involvement of the radiocarpal joints.	Addresses symptomatic radiocarpal arthritis and can improve scaphoid flexion deformities and some carpal collapse parameters.	Does not address any midcarpal arthritis, risk of nonunion, does not address proximal capitate migration and some associated alterations of wrist kinematics. Risk of increasing midcarpal arthritis as the primary location of wrist motion. Salvage is total wrist arthrodesis.	Wrist ROM of 35% to 53% of contralateral. Reported nonunion rates between 0% and 25%. Reported rates of midcarpal arthritis between 35% and 53%.	35,36
Scaphocapitate arthrodesis	Arthrodesis of the scaphocapitate articulation after reducing the scaphoid flexion and proximal capitate migration of deformities.	Late-stage Kienböck disease with relative preservation of the radioscaphoid articulation.	May improve carpal collapse parameters. Offloads the lunate, especially in fragmented or resorbed lunates with proximal capitate migration. Partial or total lunatectomy can be performed concomitantly. Can be done in late-stages of disease.	Risks of nonunion, ulnar translation of the carpus, and progressive radioscaphoid arthritis. Salvage is total wrist arthrodesis.	Average flexion-extension arc of 64°-87°, grip strengths of 19% to 83% of contralateral, VAS improvement from 6.6 to 2.8. Zero nonunions. Pain improvement in 74%, increased grip strength, average flexion-extension arc of 66°.	37,38
Scaphotrapezio-trapezoid arthrodesis	Arthrodesis of the scaphotrapezio-trapezoid articulation with correction of scaphoid flexion deformity.	Late-stage Kienböck disease with relative preservation of the radioscaphoid articulation.	Offloads the central pillar of the wrist by increasing load bearing of the radial pillar. Well-studied outcomes and risk profile across various diseases.	Does not directly address any arthritis of the radiolunate, capitolunate, or radioscaphoid articulations, only provides some offloading of the intermediate column, risk of nonunion, risk of radioscaphoid arthritis as the primary location of load bearing. Salvage is total wrist arthrodesis.	Average flexion-extension arc of 66°-69°, grip strengths of 68% of contralateral side. Deterioration of flexion-extension arc from 54% to 39% of contralateral at 1 year, grip strength improvement from 52.9% to 62.1% of contralateral, slightly improved Mayo wrist scores from 50.6 to 58.	39,40

MFT = medial femoral trochlea

and 40% of normal have been reported. Midcarpal arthritis has a tendency to develop over time, with reported rates ranging from 35% to 53%. Distal pole excision may decrease nonunion rates by decreasing the level arm of the scaphoid and unlocking the RSL arthrodesis site, contributing to further wrist ROM and potentially decreasing the development of secondary midcarpal arthritis.[36]

SC has been applied for late stage Kienböck disease. Iorio et al performed a retrospective review of patients with Lichtman stage IIIa and IIIb who underwent an SC arthrodesis, two of whom had STT-C arthrodesis. In 12 patients, a mean flexion-extension arc of 53° was obtained, VAS pain score improvement from 6.6 to 2.8, with zero nonunions.[37] They also reviewed the literature on SCA and PRC. In the literature, they found a flexion-extension arc range of 64° to 87° and grip strengths of 19% to 83% in patients with SCA. Those with a PRC had a reported flexion-extension arc range of 69% to 115% degrees and grip strengths of 48% to 94%.

Rhee et al[38] published their experience with SC arthrodesis in Lichtman stage III and IV patients combined with subtotal or total lunatectomy. They identified 27 patients and reported zero nonunions, pain improvement in 74%, a mean flexion-extension arc of 66°, and increased grip strength. They also found asymptomatic radiographic carpal collapse and ulnar translation of the carpus.

Watson et al[39] reviewed 105 patients who had Kienböck disease who received an STT arthrodesis. They found that patients with Kienböck had a postoperative flexion/extension arc of 46° and 41°, respectively (69% and 66% of contralateral wrist), and a grip strength of 68% of the contralateral side, which was markedly worse than in other diagnosis treated with PRC. Hohendorff et al looked at STT arthrodesis versus PRC for Lichtman stage IIIb patients prospectively and found that patients with a PRC markedly outperformed those with an STT arthrodesis. At one year, they found the STT treatment group experienced worsening of their mean flexion/extension from 54% to 39% of the contralateral arm (62% to 57% in PRC), grip strength improvement, 52.9% to 62.1% of contralateral (39% to 69% in PRC), and slightly improved Mayo Wrist Scores from 50.6 to 58 (PRC 54.6 to 66).[40]

Summary

Although Kienböck disease has been a topic of great debate and discussion regarding the optimal treatment of the various stages of disease, there have been little data to advance our understanding of the etiology and pathophysiology of the disease process. Nor has there been a proven or ideal treatment option for the various stages and anatomic vagaries that exist in Kienböck disease (Flow Chart 1, Supplemental Digital Content 1, http://links.lww.com/JAAOS/A479 and Flow Chart 2, Supplemental Digital Content 2, http://links.lww.com/JAAOS/A480, Table 1). Our experience has become the culmination of the world's case series and reports, with most studies demonstrating positive outcomes.

There is a tremendous need for a randomized, multicenter evaluation of the various treatment options with standardized outcomes measures.

Early accurate diagnosis with appropriately chosen intervention (immobilization, joint leveling, decompression, and vascularized bone grafting) may prevent progression of the disease process. Early stage disease typically responds fairly to careful and thoughtful treatment. With moderate to advanced stages, a thorough discussion between the surgeon and the patient weighing the risks and benefits of each surgical option and its outcomes is necessary. Surgeon comfort level, accurate evaluation, realistic patient expectations, and detailed understanding of the experiences of the treatment of Kienböck disease over the past several decades all play a critical role in determining the optimal outcome for the patient.

References

References printed in **bold type** are those published within the past 5 years.

1. Gelberman RH, Bauman TD, Menon J, Akeson WH: The vascularity of the lunate bone and Kienböck's disease. *J Hand Surg Am* 1980;5:272-278.
2. Freedman DM, Botte MJ, Gelberman RH: Vascularity of the carpus. *Clin Orthop Relat Res* 2001:47-59.
3. Schuind F, Cooney WP, Linscheid RL, An KN, Chao EY: Force and pressure transmission through the normal wrist. A theoretical two-dimensional study in the posteroanterior plane. *J Biomech* 1995;28: 587-601.
4. Ledoux P, Lamblin D, Wuilbaut A, Schuind F: A finite-element analysis of Kienbock's disease. *J Hand Surg Eur Vol* 2008;33: 286-291.
5. Viegas SF, Wagner K, Patterson R, Peterson P: Medial (hamate) facet of the lunate. *J Hand Surg Am* 1990;15:564-571.
6. Haase SC, Berger RA, Shin AY: Association between lunate morphology and carpal collapse patterns in scaphoid nonunions. *J Hand Surg Am* 2007;32:1009-1012.
7. Rhee PC, Jones DB, Moran SL, Shin AY: The effect of lunate morphology in Kienböck disease. *J Hand Surg Am* 2015; 40:738-744.
8. Yazaki N, Burns ST, Morris RP, Andersen CR, Patterson RM, Viegas SF: Variations of capitate morphology in the wrist. *J Hand Surg Am* 2008;33:660-666.
9. Keith PP, Nuttall D, Trail I: Long-term outcome of nonsurgically managed Kienböck's disease. *J Hand Surg Am* 2004; 29:63-67.
10. Fujisawa K, Hitoshi H, Yoshihiro T, Yasumitsu H, Akimasa M, Matsumoto M: Long-Term follow up of patients with conservatively treated Kienböck's disease. *J Orthopaedic Sci* 1996;1:182-186.
11. Amadio PC, Hanssen AD, Berquist TH: The genesis of Kienböck's disease: Evaluation of a case by magnetic resonance imaging. *J Hand Surg Am* 1987;12: 1044-1049.
12. Lichtman DM, Lesley NE, Simmons SP: The classification and treatment of Kienbock's disease: The state of the art and a look at the future. *J Hand Surg Eur Vol* 2010;35:549-554.
13. Bain GI, Begg M: Arthroscopic assessment and classification of Kienbock's disease. *Tech Hand Up Extrem Surg* 2006;10:8-13.
14. **Lichtman DM, Pientka WF II, Bain GI: Erratum: Addendum: Kienböck disease: A new Algorithm for the 21st century. *J Wrist Surg* 2017;6:e1-e2.**
15. Ståhl F: On lunatomalacia (Kienböck's disease): a clinical and roentgenological study, especially on its pathogenesis and late results of immobilization treatment. *Acta Chir Scand* 1947;126(suppl):1-133.
16. Illarramendi AA, Schulz C, De Carli P: The surgical treatment of Kienböck's disease by radius and ulna metaphyseal core decompression. *J Hand Surg Am* 2001;26: 252-260.
17. Sherman GM, Spath C, Harley BJ, Weiner MM, Werner FW, Palmer AK: Core decompression of the distal radius for the treatment of Kienböck's disease: a biomechanical study. *J Hand Surg Am* 2008;33:1478-1481.
18. **Zaidenberg EE, De Carli P, Boretto JG, et al: Descompresión ósea metafisaria del radio distal para estadios tempranos de la**

enfermedad de Kienböck. Seguimiento mínimo de 10 años. *Revista de Ortopedia y Traumatología* 2018;83:25-30.

19. Mehrpour SR, Kamrani RS, Aghamirsalim MR, Sorbi R, Kaya A: Treatment of Kienböck disease by lunate core decompression. *J Hand Surg Am* 2011;36: 1675-1677.

20. Horii E, Garcia-Elias M, Bishop AT, Cooney WP, Linscheid RL, Chao EY: Effect on force transmission across the carpus in procedures used to treat Kienböck's disease. *J Hand Surg Am* 1990;15:393-400.

21. Koh S, Nakamura R, Horii E, Nakao E, Inagaki H, Yajima H: Surgical outcome of radial osteotomy for Kienböck's disease-minimum 10 years of follow-up. *J Hand Surg Am* 2003;28:910-916.

22. Zenzai K, Shibata M, Endo N: Long-term outcome of radial shortening with or without ulnar shortening for treatment of Kienbock's disease: a 13-25 year follow-up. *J Hand Surg Br* 2005;30:226-228.

23. Wada A, Miura H, Kubota H, Iwamoto Y, Uchida Y, Kojima T: Radial closing wedge osteotomy for Kienböck's disease: an over 10 year clinical and radiographic follow-up. *J Hand Surg Br* 2002;27:175-179.

24. Gay AM, Parratte S, Glard Y, Mutaftschiev N, Legre R: Isolated capitate shortening osteotomy for the early stage of Kienböck disease with neutral ulnar variance. *Plast Reconstr Surg* 2009;124:560-566.

25. Moritomo H, Murase T, Yoshikawa H: Operative technique of a new decompression procedure for Kienböck disease: partial capitate shortening. *Tech Hand Up Extrem Surg* 2004;8:110-115.

26. Singer MS, Essawy OM, Farag HE: Early results of partial capitate shortening osteotomy in management of Kienböck disease. *Curr Orthopaedic Pract* 2017;28: 297-302.

27. Takase K, Imakiire A. Lunate excision, capitate osteotomy, and intercarpal arthrodesis for advanced Kienböck disease. Long-term follow-up. *J Bone Joint Surg Am* 2001;83:177-83.

28. Ruettermann M: Lunate excision, capitate osteotomy, and intercarpal arthrodesis should be used with caution for advanced Kienböck's disease. *J Hand Surg Eur Vol* 2019;44:112-113.

29. Elhassan BT, Shin AY: Vascularized bone grafting for treatment of Kienböck's disease. *J Hand Surg Am* 2009;34:146-154.

30. Moran SL, Cooney WP, Berger RA, Bishop AT, Shin AY: The use of the 4 + 5 extensor compartmental vascularized bone graft for the treatment of Kienböck's disease. *J Hand Surg Am* 2005;30:50-58.

31. Fujiwara H, Oda R, Morisaki S, Ikoma K, Kubo T: Long-term results of vascularized bone graft for stage III Kienböck disease. *J Hand Surg Am* 2013;38:904-908.

32. Bürger HK, Windhofer C, Gaggl AJ, Higgins JP: Vascularized medial femoral trochlea osteochondral flap reconstruction of advanced Kienböck disease. *J Hand Surg Am* 2014;39:1313-1322.

33. Croog AS, Stern PJ: Proximal row carpectomy for advanced Kienböck's disease: average 10-year follow-up. *J Hand Surg Am* 2008;33:1122-1130.

34. Chim H, Moran SL: Long-term outcomes of proximal row carpectomy: a systematic review of the literature. *J Wrist Surg* 2012; 1:141-148.

35. McGuire DT, Bain GI: Radioscapholunate fusions. *J Wrist Surg* 2012;1:135-140.

36. Garcia-Elias M, Lluch A, Ferreres A, Papini-Zorli I, Rahimtoola ZO: Treatment of radiocarpal degenerative osteoarthritis by radioscapholunate arthrodesis and distal scaphoidectomy. *J Hand Surg Am* 2005;30: 8-15.

37. Iorio ML, Kennedy CD, Huang JI: Limited intercarpal fusion as a salvage procedure for advanced Kienbock disease. *Hand (N Y)* 2015;10:472-476.

38. Rhee PC, Lin IC, Moran SL, Bishop AT, Shin AY: Scaphocapitate arthrodesis for Kienböck disease. *J Hand Surg Am* 2015; 40:745-751.

39. Watson HK, Wollstein R, Joseph E, Manzo R, Weinzweig J, Ashmead D IV. Scaphotrapeziotrapezoid arthrodesis: a follow-up study. *J Hand Surg Am* 2003;28:397-404.

40. Hohendorff B, Mühldorfer-Fodor M, Kalb K, van Schoonhoven J, Prommersberger KJ: STT arthrodesis versus proximal row carpectomy for Lichtman stage IIIB Kienböck's disease: first results of an ongoing observational study. *Arch Orthop Trauma Surg* 2012;132:1327-1334.