

Radiologic Guide to Surgical Treatment of Kienbock's Disease

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Abstract

Kienbock's disease, or avascular necrosis of the lunate, is a progressive disease ultimately resulting in end-stage arthritis. Various surgical treatments are available for different Lichtman stages of disease. This article reviews surgical treatments of Kienbock's disease from a radiologic perspective. The reader will learn preoperative indications and imaging, normal and abnormal post-surgical appearance and potential complications of operative treatments of Kienbock's disease.

Introduction

Kienbock's disease is defined as avascular necrosis of the lunate bone, which may ultimately progress to lunate sclerosis, collapse, and wrist instability. Incidence is highest in males 20-40 years of age, although it may occur in any age group. Kienbock's disease is uncommon in skeletally immature patients. The cause of Kienbock's disease is likely multi factorial, but potential risk factors have been identified including variant lunate arterial supply and ulnar negative variance. The lunate typically receives both volar and dorsal blood supply through the palmar and dorsal radiocarpal arches, which arise from the terminal branches of the radial, ulnar, and anterior interosseous arteries. In fewer than 20% of patients, the dorsal blood supply is absent and the lunate is supplied by the palmar radiocarpal arch only; this may represent a risk factor for Kienbock's disease [1]. Negative ulnar variance may also predispose to Kienbock's disease due to abnormal force loading on the lunate. Higher observed prevalence of negative ulnar variance was first noted in patients with Kienbock's disease in the 1920's [2,3]. However, some investigators have recently challenged this theory [4].

Kienbock's disease may be staged according to radiologic appearance using Lichtman classification (Table 1) [3]. Stage I is defined as normal radiographic appearance of the lunate with marrow edema present on MRI. In Stage II disease, there is sclerosis of the lunate, with or without a fracture line, but without lunate collapse. Stage III, defined as presence of lunate articular surface collapse, may be divided further into three subcategories. In Stage IIIA, there is no scaphoid rotation; in Stage IIIB, there is fixed scaphoid rotatory subluxation, and in Stage IIIC, a coronal fracture of the lunate is present in addition to scaphoid rotation. Of note, Lichtman *et al.* proposed Stage III C in 2010 [3] as an addition to the classification scheme. Stage IV disease is present when secondary radiocarpal or midcarpal osteoarthritis is present in addition to Stage III findings. For comprehensive review of radiographic and MRI appearance of Kienbock's disease by Lichtman stage, see Arnaiz *et al.* [5]. An alternate classification of Kienbock's disease, the Bain and Begg

Table 1: Kienbock's Disease Progression: Lichtman Staging [3].

Stage I	Radiographically normal; increased T2 signal on MRI
Stage II	Sclerosis of lunate, +/- fracture line
Stage III	Lunate articular surface collapse
A	Without scaphoid rotation
B	With fixed scaphoid rotation
C	With coronally oriented lunate fracture
Stage IV	Lunate collapse with secondary radiocarpal osteoarthritis



Figure 1: (A) Posterioranterior, (B) oblique, and (C) lateral radiographs of the wrist in a 15-year-old boy with stage II Kienbock's disease showing post-surgical appearance of radial shortening osteotomy with bridging plate and screws. No persistent ulnar negative variance is present.

classification system, in which disease stage is based upon number of nonfunctional articular surfaces of the lunate at arthroscopy, may be preferred by some surgeons [6].

Lichtman stage I Kienbock's disease is typically treated with immobilization. For stage I Kienbock's disease refractory to immobilization, as well as later stage Kienbock's disease, surgical treatment is preferred [7]. A range of surgical treatments is available depending on the stage of disease, ulnar variance, patient age, and surgeon preference. It is important for the radiologist to recognize the surgical treatments of Kienbock's disease; however, no guide to normal and abnormal post-surgical appearance of Kienbock's disease currently exists in the radiology literature. This paper will illustrate the expected post-surgical appearance of common surgical treatments of Kienbock's disease and their complications.

Radial Shortening Osteotomy

Radial shortening osteotomy is the most commonly performed surgery for early stage (II-IIIa) Kienbock's disease in the setting of negative ulnar variance and may also be used to treat stage I disease refractory to splinting [7]. Radial shortening osteotomy is performed as a joint leveling procedure to correct potentially pathologic force loading on the lunate; it may be performed in tandem with vascularized bone grafting [8]. Multiple studies have shown symptomatic improvements post-surgically [9,10], although a meta-analysis suggested that radiographic disease stage may continue to

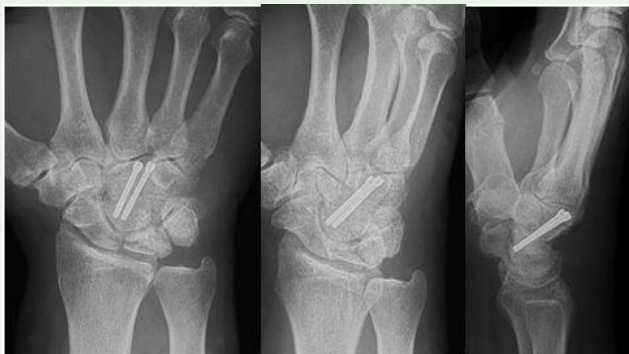


Figure 2: (A) Posterioranterior, (B) oblique and (C) lateral radiographs of the wrist in a 51-year-old man with Lichtman stage IIIa disease showing post-surgical appearance of capitate shortening osteotomy with traversing compression screws.



Figure 3: Posterioranterior radiograph showing nonunion of capitate shortening osteotomy in a 55 year old man with Lichtman stage IIIa disease. Note the well-corticated margins of the capitate fragments (arrows). Traversing compression screws remain in position without loosening or fracture. Also noted is presence of ulna negative variance.

progress [11]. Radiographic findings include osteotomy defect within the radius, usually with plate and screw fixation (Figure 1). Ulnar variance should be assessed on post-surgical imaging and should be neutral or minimally positive (up to 1mm). Complications include nonunion and hardware infection but are relatively infrequent. Radial overgrowth may occur as a consequence of this procedure in a skeletally immature patient [12]. Post-surgical radiographs should also monitor for disease progression, a sign of treatment failure.

Capitate Shortening Osteotomy

Capitate shortening osteotomy is performed for early (stage



Figure 4: (A) Posterioranterior, (B) oblique, and (C) lateral radiographs showing post-surgical appearance of pedicled bone graft to lunate in a 31-year-old man with Lichtman stage IIIa disease with simultaneous capitate and hamate shortening osteotomies. A surgical staple marks the site of bone graft placement (arrow). Debridement of the lunate (sequestrectomy) and packing of the lunate with autogenous bone from distal radius (harvest site: *) also performed. Pedicled bone graft harvest site at 3rd metacarpal base is not well seen.



Figure 5: (A) Posterioranterior and (B) oblique views of the wrist in a 31-year-old man with Lichtman stage IIIA disease showing post-surgical appearance of scaphocapitate fusion with Acutrak compression screw fixation.

II-III A) Kienbock's disease for lunate unloading in patients with positive or neutral ulnar variance. This procedure may also be performed in patients with negative ulnar variance, but radial shortening osteotomy is typically preferred in that clinical setting [7]. This technique has shown promising results in several studies [13,14]. Hamate shortening osteotomy may be performed as an alternative to or in conjunction with capitate shortening osteotomy. As with radial shortening osteotomy, capitate shortening osteotomy may be performed with vascularized bone grafting or posterior interosseous neurectomy. Radiographic findings include osteotomy defect within the capitate, typically transfixed by one or more compression screws (Figure 2). The main complications include nonunion (Figure 3) and hardware infection. Post-surgical radiographs should also monitor for disease progression/treatment failure, as above.

Pedicle or Vascularized Bone Graft

Pedicle bone grafting is used to treat early-stage (II-III A) Kienbock's disease and is often performed in conjunction with an off-loading procedure (such as capitate shortening osteotomy and/

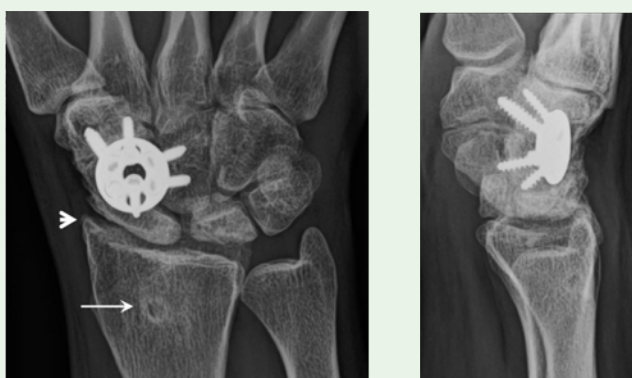


Figure 6: Post-surgical posterior anterior and lateral radiographs in a 24-year-old woman with Lichtman stage IIIB disease after partial carpal arthrodesis with spider plate and auto graft placement. Joint spaces between the capitate, trapezium, and trapezoid are still visible in this patient. Note the corrected scaphocapitate angle. There has also been a minimal radial styloidectomy (arrowhead). Arrow indicates auto graft harvest site.



Figure 7: 42 year old woman with advanced Kienbock's disease (preoperative Lichtman stage not available) status post scaphocapitate fusion. Posterior anterior radiograph with migration of screw tips into the carpometacarpal joint space (arrow). Note lunate sclerosis and articular surface collapse. There is a retained K-wire fragment in the 4th metacarpal and a foreign object overlying the 5th metacarpal.

or radial shortening osteotomy, as above). A recent meta-analysis showed improved grip strength and range of motion in both early and late stage disease patients who underwent vascularized bone grafting [11]. The distal radius is most commonly used as a donor site, and the fourth and fifth extra compartmental arteries (branches of the posterior division of the anterior interosseous artery) typically form the pedicle [15]. The bone graft is taken from the distal radius 1 cm proximal to the radiocarpal joint. Other less common bone graft donor sites include from the metacarpal base, vascularized pisiform and free iliac crest bone graft [8]. Radio graphically, the appearance of the graft harvest site is a focal defect or an area of sclerosis, most commonly at the distal radius as described above. A surgical staple

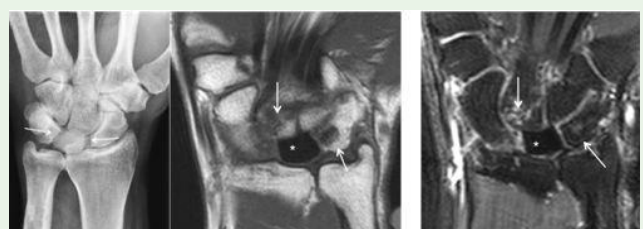


Figure 8: (A) Posterioranterior radiograph shows lunate excision and placement of silicone prosthesis (arrows) in a 32 year old woman with prior Lichtman stage III disease. Note smooth appearance of prosthesis and lack of bony trabeculae. 15 months after surgery, coronal T1 (B) and T2 fat saturated (C) MR images are obtained and show homogeneous low T1 and T2 signal intensity within the silicone prosthesis (*). T1 isointense/T2 hyperintense lesions (arrows) within the triquetrum and capitate represent subchondral cysts related to silicone synovitis.



Figure 9: (A) Posterior-anterior, (B) oblique, and (C) lateral radiographs of the wrist in a 61-year-old woman with prior Lichtman stage IV disease showing post-surgical appearance of proximal row carpectomy. The lunate, scaphoid, and triquetrum are absent. The capitate head articulates with the lunate fossa (arrowheads). Note ulna negative variance and suture anchor placed during radiocarpal joint repair (arrows).

may be present at the site of the bone graft placement at the lunate. Compared to pre-operative films, the lunate may appear less sclerotic secondary to sequestrectomy and packing of the lunate with normal bone (Figure 4). The primary complication of this surgery is failure of lunate revascularization with subsequent progression of disease. Hardware complications relating to the off-loading procedure, as described above, may also be present.

Partial Carpal Arthrodesis

Partial carpal arthrodesis is typically used to stabilize the scaphoid and correct carpal alignment in later (stage IIIB-IV) disease with scaphoid rotation. Partial carpal arthrodesis can entail scaphocapitate fusion, where the scaphocapitate alignment is corrected without fusion of the remaining carpal bones (Figure 5) or can be more extensive, with fusion of the trapezium and trapezoid as well as the capitate and scaphoid [8]. With more extensive partial carpal arthrodesis, a spider plate and screws may be used (Figure 6). This may be performed in conjunction with a radial styloidectomy (Figure 6). When evaluating post-operative radiographs for partial carpal arthrodesis, the scaphocapitate angle should be normalized compared to the preoperative films. In several studies, no advantage has been shown for partial carpal arthrodesis over other procedures such as radial shortening osteotomy and total carpal arthrodesis.



Figure 10: (A) Posterior-anterior wrist radiograph of 41 year old man with prior Lichtman stage IV disease immediately after proximal row carpectomy. (B) Shows posterior-anterior radiograph obtained at 12 month follow-up, showing narrowing at the articulation between the capitate and the lunate fossa with increased sclerosis (arrows), consistent with progression of osteoarthritis.

However, the procedure remains a less invasive alternative to total carpal arthrodesis [11,16]. Potential complications include hardware loosening, hardware failure, migration of hardware into the joint space (Figure 7), and treatment failure with continued disease progression.

Lunate Excision

Lunate excision may be performed along with carpal arthrodesis. Although there was initial enthusiasm for silicone prosthesis placement following lunate excision, silicone prostheses are no longer commonly used due to a high rate of silicone synovitis and need for implant removal [17]. Radiographically, silicone prostheses may be recognized due to smooth contours and lack of internal trabeculae (Figure 8). On MRI, silicone prosthesis will display uniformly low signal on both T1 and T2 weighted images (Figure 8). Radiographic evidence of silicone synovitis includes formation of bone cysts in adjacent bones, with or without adjacent intercarpal joint space narrowing (Figure 8).

Proximal Row Carpectomy

Proximal row carpectomy is typically performed as a salvage procedure for symptom relief in advanced (stage IIIB-IV) disease. The procedure involves removal of the entire proximal carpal row (lunate, scaphoid, and triquetrum). In order to successfully perform proximal row carpectomy, the capitate head must be relatively intact as it will articulate with the lunate fossa of the distal radius post-surgically (Figure 9) [7,18]. This procedure may be performed along with a posterior interosseous neurectomy for pain relief. Proximal row carpectomy is relatively contraindicated for young patients since a potential complication of this surgery is development of secondary osteoarthritis at the articulation of the capitate head and the distal radius over time (Figure 10) [18].

Conclusion

Kienbock's disease, although relatively uncommon, is associated with progressive morbidity and often requires surgical intervention. Radiologists should be familiar with the appearance of Kienbock's disease and its common surgical treatments.

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