Article published online: 2024-01-15

Simplifying the Decision-Making Process in the Treatment of Kienböck's Disease

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J Wrist Surg 2024;13:294–301.

Abstract

Background In recent years, the classification and treatment algorithm for adult Kienböck's disease (KD) has expanded. However, the priority of the investigations done in determining its management has not been discussed, as not every patient with KD requires magnetic resonance imaging (MRI) or wrist arthroscopy.

Materials and Methods We discuss the role of these investigations and emphasize the importance of computed tomography (CT) imaging in evaluating the cortical integrity of the lunate and its role in the decision-making process and management of KD.

Results We put forward an investigative algorithm that places into context the investigative roles of MRI, arthroscopy, and CT.

Conclusion KD is a rare condition, and there is a lack of comparative studies to help us choose the preferred treatment. The decision on the management options in adult KD may be made by determining the integrity of the lunate cortex and deciding whether the lunate is salvageable or not by CT scan. MRI may provide useful information on the vascular status if the lunate cortex is intact, and the lunate is salvageable. If the lunate is fragmented, it is not salvageable, and MRI does not provide useful information. Arthroscopy has a role in selective cases.

Keywords
- Kienböck disease
- imaging
- classification

The decision-making process for the management of adult Kienböck disease (KD) has become complex and may be due to many theories about its pathogenesis,[1,2] various surgical treatments proposed,[2–5] and many questions that remain unanswered.[6] Various recently published review articles offer different perspectives on the evaluation and management of KD.[1–5,7] The Lichtman, Schmitt, and Bain[4] (LSB) classification guides the management of KD by using plain radiograph, magnetic resonance imaging (MRI), and arthroscopic findings to determine the bony, vascular, and chondral status of the lunate. Camus and Van Overstraeten expanded the LSB classification and included patient age groups and other treatment options not previously included in the LSB algorithm, such as nonvascularised rib graft and denervation.[1] Despite minor differences, the general principles of treatment are as follows: (1) manage nonoperatively in the young or elderly where possible; (2) protect the lunate if the lunate is intact; (3) reconstruct the lunate if it is salvageable; (4) replace, remove, or bypass the lunate if it is not salvageable; (5) preserve the radiocarpal and/or the midcarpal joint when it is possible; and (6) when pan carpal arthritis occur, consider other salvage procedures such as wrist replacement or total wrist arthrodesis. However, Bhardwaj et al[3] pointed out the key issues with such unifying guidelines, including

received
September 11, 2023
accepted
December 5, 2023
article published online
January 15, 2024

Thieme Medical Publishers, Inc.,
333 Seventh Avenue, 18th Floor,
New York, NY 10001, USA

DOI https://doi.org/10.1055/s-0043-1778064.
ISSN 2163-3916.

the lack of consensus in the treatment options, the lack of evidence, and the ongoing debate on the natural progression of KD. This sentiment was also shared by Chojnowski et al.[5] Squitieri et al[8] warned about the potential for publication bias in a condition such as KD, where the availability of comparative studies is limited.

As KD is an uncommon condition, with an estimated prevalence of 7 in 100,000 patients, based on a retrospective review of over 150,000 radiographs,[9] conducting randomized controlled trials for this condition is difficult. As a result, it can be challenging to make unbiased, evidence-based surgical decisions. The purpose of this manuscript is to provide a perspective and discuss several important questions surrounding the order or priority of investigations including where MRI and arthroscopy may be useful investigations in its management. Additionally, we propose an investigative algorithm, including the role of computed tomography (CT) of the lunate to guide the decision-making process for managing this disease (►**Fig. 1**).

Does Magnetic Resonance Imaging Alter Surgical Management?

MRI scan is important in the diagnosis of Lichtman's Stage I KD[2] particularly in the early stages of the disease when the plain radiographic changes are not apparent[6] (►**Fig. 2a, b**). In KD, it may provide important clues to the status and extent of vascularity of the lunate and the chondral condition of the articular surfaces[10] and act as a guide for the need of revascularization or joint motion-preserving procedures.

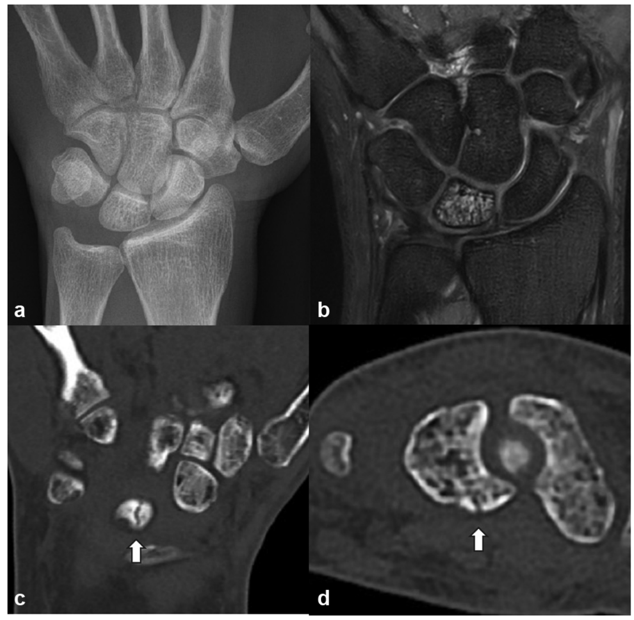

Fig. 2 (**a**) Plain radiograph of wrist with no evidence of lunate sclerosis. (**b**) T2 weighted image with increase signal in lunate. (**c**) Coronal CT slice image. Arrow indicating fracture of palmar rim of lunate. (**d**) Axial CT slice image. Arrow indicating fracture of palmar rim of lunate.

The Accuracy of Magnetic Resonance Imaging in Determining the Vascular Status of the Lunate

In 1997, Schmitt et al proposed three stages of lunate vascularity in KD with radiographic changes varying from edema to complete necrosis based on the images in

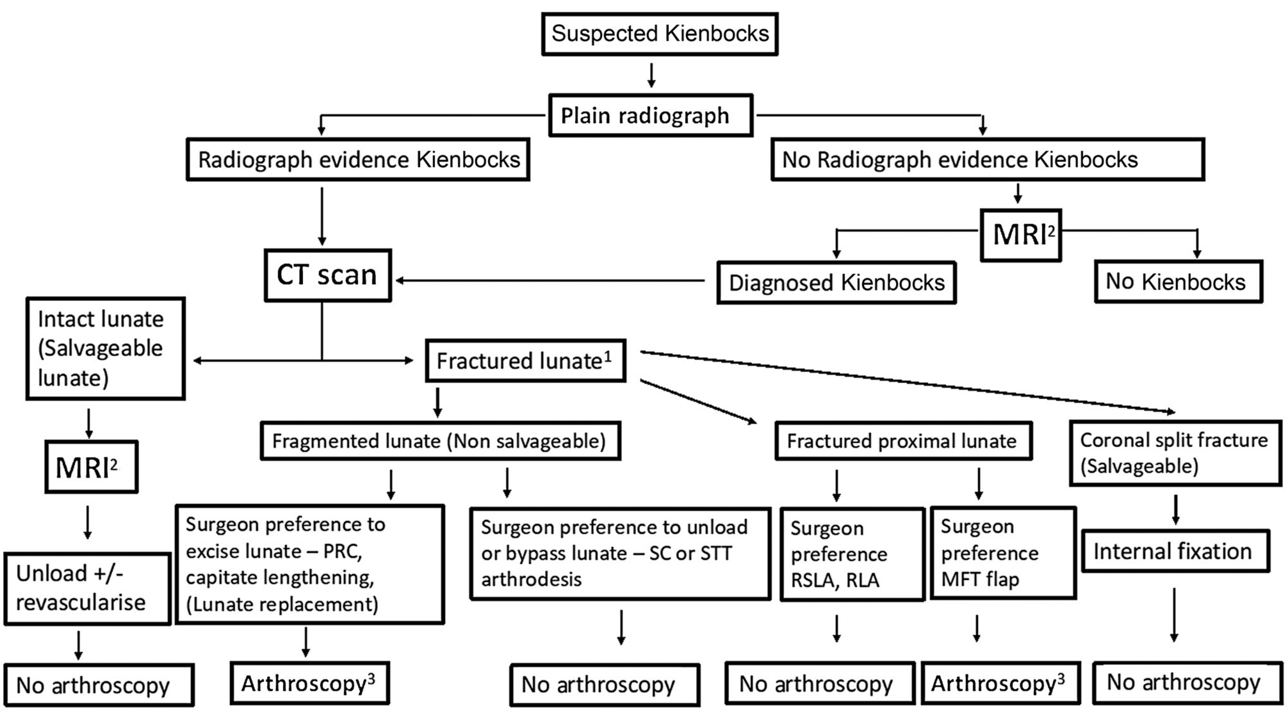

Fig. 1 An investigative algorithm.[1] CT scan to determine if lunate fracture involves the whole lunate with fragmentation, the proximal articular surface only, or a coronal split fracture.[2] Accuracy of MRI scan in determining vascularity of lunate is controversial. See main text.[3] Arthroscopy to evaluate relevant articular surfaces but not lunate. MFT, medial femoral trochlear; PRC, proximal row carpectomy; RLA, radiolunate arthrodesis; RSLA, radioscapholunate arthrodesis; SC, scaphocapitate; STT, scaphotrapezialtrapezoid.

gadolinium perfusion enhanced fat-suppressed T1-weighted sequence on MRI.[11] Lichtman theorized that the results from MRI would have implications on the decisions on revascularization procedures by defining the zones of vascularity.[10] In their 2016 update,[2] they suggested that revascularization procedures were an option if the MRI showed a nonhomogenous signal with contrast enhancement of the reparative zone and viable distal bone and a necrotic proximal lunate, referred to as Stage II. In Stage III, there was no contrast enhancement indicating complete lunate osteonecrosis.

However, other studies that examined the correlation of MRI in evaluating bone perfusion to the histopathology of the excised lunate have questioned the accuracy of MRI in determining the diagnosis of a necrotic or reparative lunate.[12–14] Dias and Lunn[6] also argued that beyond identifying stage 1 disease, there was little established practical use of MRI scans. In a systematic review, the diagnostic accuracy of MRI in detecting early osteonecrosis of the femoral head was reported to have a sensitivity and specificity of 93.0% (95% confidence interval [CI]: 92.0–94.0%) and 91.0% (95% CI: 89.0%–93.0%), respectively.[15] In light of this conflicting information, the interpretation of MRI findings should be used as a guide.

The Evidence Behind Revascularization Procedures

Several revascularization procedures have been described including that originally described by Hori et al[16] using a vascular pedicle. Other locoregional pedicled bone flaps[17] or free vascularized bone transfers[18,19] have been described. However, the supporting literature for these techniques was from case series. They reported favorable outcomes but were without a control group. While the idea of revascularization appears to address the presumptive underlying problem of vascular insufficiency, there is some evidence that the lunate may revascularize without the need for direct revascularization.[6] There are other confounding factors. Lunate collapse in KD is thought likely to be the result of revascularization and resorption of the subchondral bone resulting in weakness and subchondral fracturing.[6,20] In addition, indirect revascularization of the lunate has been reported to occur after nonrevascularization-related procedures such as metaphyseal core decompression.[21]

As the accuracy of MRI scans in determining the vascular perfusion of the lunate has not been established and there is uncertainty in the available evidence supporting the role or the need for revascularisation,[22] the decision to revascularize the lunate is left to the individual surgeon. If revascularization is thought to be necessary, the vascular perfusion status of the lunate may be evaluated by MRI or intraoperatively, looking for punctate bleeding after perforation by a fine Kirschner wire.

How Does Arthroscopy Aid in The Decision-Making?

Arthroscopic assessment of the chondral surfaces between the lunocapitate and radiolunate joints was advocated by Bain and Begg[23] and the expanded algorithm for the treatment of KD[4] suggested that chondropathy necessitated the removal or reconstruction of the lunate. However, Dias and Lunn[6] reported that the chondral envelope of the lunate may remain intact despite fragmentation of the underlying subchondral bone (►**Fig. 3a,b**). Wrist arthroscopy may also exaggerate the loss of the "functional" chondral surface.[24] Arthroscopic evaluation of the chondral surface of the lunate fossa and proximal capitate is however useful if joint motion procedures such as proximal row carpectomy (PRC), capitate lengthening[25] or radioscapholunate (RSL) arthrodesis are the preferred treatment options

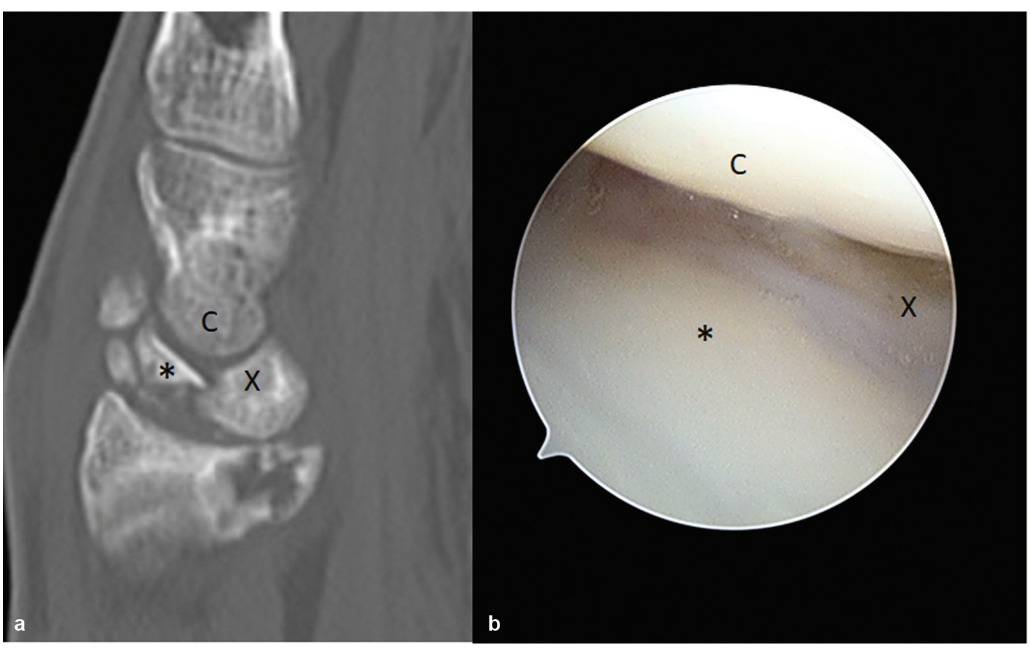

Fig. 3 (**a**) Sagittal CT image of Kienböcks disease with fragmented lunate. (**b**) Arthroscopy of midcarpal joint. C, capitate; *, articular surface of dorsal lunate fragment; X, articular surface of volar lunate fragment.

when there is lunate collapse and comminution, and the lunate is not considered salvageable. However, in similarly collapsed and nonsalvageable lunates, the evaluation of these chondral surfaces becomes less relevant if limited wrist arthrodesis procedures such as scaphocapitate (SC) or scapho-trapezial-trapezoidal (STT) arthrodesis, to bypass the lunate, are the preferred surgical options. We are not aware of any reports indicating the incidence of degeneration of the radio-scaphoid joint in KD, and hence, evaluation of this joint is unnecessary. Arthroscopic synovectomy and removal of loose bodies may relieve pain; however, there is no evidence to support the role of arthroscopy for this purpose in the management of KD.

How Does Computed Tomography Aid in The Decision-Making

Determination of the Lunate Cortical Integrity

In a review of the available procedures for KD,[4,5] the presence of a lunate where its cortical integrity is intact will determine if the lunate can be salvaged, that is, the lunate bone can be preserved in its entirety and the wrists treated by core decompression, lunate unloading, or revascularization procedures. In these cases, every attempt is made to preserve the lunate by addressing the potential underlying pathological process, that is, the loading stress and its blood supply. If the distal cortical surface of the lunate is intact but the proximal lunate articular surface is collapsed (►**Fig. 4**), then reconstruction by an osteochondral flap to the proximal lunate[18,19] may be considered. In cases where there is evidence of loss of both the distal and proximal lunate cortical integrity, typically in the presence of fragmentation on plain radiograph or CT scan (►**Fig. 3**), determination of the status of the lunate articular cartilage by arthroscopy is unnecessary as cortical collapse is thought to precede chondral loss[6] as chondral nutrition is from its surrounding synovial fluid and not from the subchondral bone. As the structural integrity of the lunate is lost, the lunate is no longer salvageable and the lunate cannot be restored structurally in the presence of bone comminution, regardless of its articular condition or vascular status. In these cases, the treatment options are lunate excision (including PRC, capitate lengthening, or lunate replacement),[26] bypassing the central column by SC or STT partial wrist arthrodesis, or arthrodesis of the radiolunate or RSL joints and total wrist arthrodesis or replacement, depending on the distribution of joint degeneration.

The modality that is best suited to determine the integrity of the lunate cortex is CT imaging.[27] In the fragmented lunate, if the preferred surgical option is to excise the lunate (including PRC, capitate lengthening, or lunate replacement), arthroscopic evaluation of the articular surfaces of the lunate fossa of the distal radius and the proximal capitate is a relevant investigation... in determining the suitability of these surgical options. Arthroscopy of the distal articular surface of the lunate is also relevant in cases where lunate collapse is confined to the proximal lunate and either radiolunate arthrodesis or medial femoral trochlear flap is the preferred surgical option. Arthroscopy is however unnecessary if the preferred surgical option in the fragmented lunate is to bypass the lunate by SC or STT arthrodesis.

Impact on Stage II and III Management

Lichtman's KD stage II and Stage III differ by the presence and degree of lunate and carpal collapse on plain radiographs. However, plain radiographs alone may not detect the presence of occult lunate fractures.[28] It is also recognized that the lunates in patients with KD stage IIIA may have an intact cortex despite the collapse in lunate height.[2] In these patients where the lunate cortex is intact, the surgical management is aimed toward salvaging and preserving the lunate, irrespective of the status of its articular cartilage. The management options are lunate decompression by lunate forage,[29] unloading the lunate by radial shortening in an ulnar-negative wrist[30] or in cases with an ulnar-neutral or -positive wrist,[31] may be treated by closing or opening wedge osteotomy, temporary pinning of the SC joint,[32,33] or capitate shortening.[5] Revascularization of the lunate either by insertion of a vascular pedicle[16] or vascularized

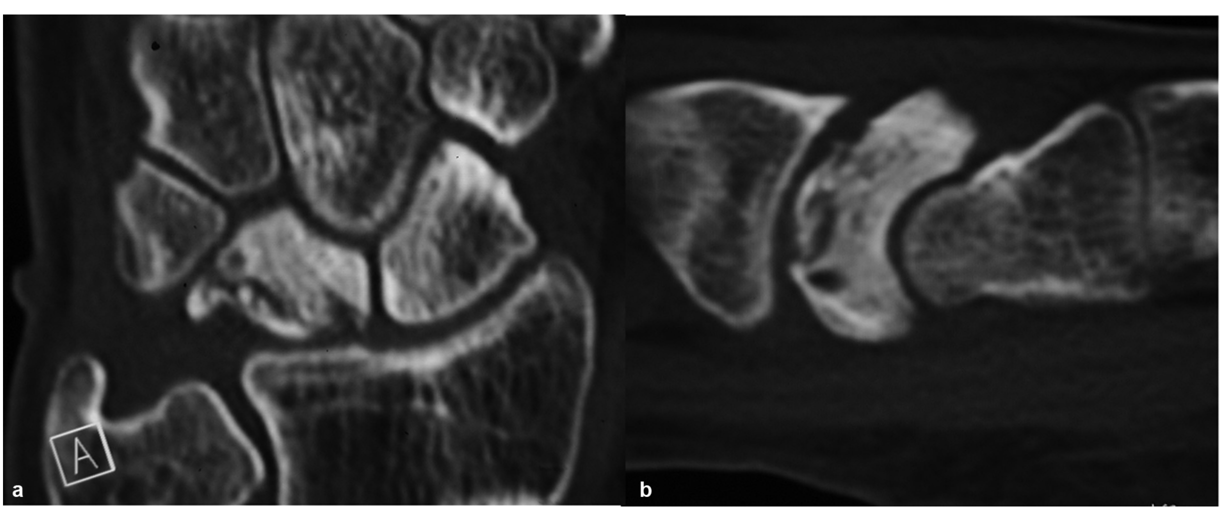

Fig. 4 (**a**) Coronal CT scan image of Kienböcks disease with collapse and comminution of proximal lunate articular surface only. (**b**) Sagittal CT scan image showing collapse and comminution of proximal lunate articular surface only.

bone graft[18] may also be performed concurrently. There is no comparative evidence[34] that helps us choose one option over the other including the need for revascularization.[17]

The lunate cortex may also remain intact in KD Stage IIIB[34] (►Fig. 5), and in these cases, the lunate remains salvageable. Here, where the lunate cortex is intact, and as every attempt is made to salvage the lunate, the status of its articular cartilage also bears little influence in surgical management.

The detection of a fragmented lunate fracture (►Fig. 3), however, will alter the management options. In these cases, there are again no comparative studies that help us choose the preferred surgical option and management of these wrists will depend on surgeon preference. These options are similar to those where the CT scan confirms the presence of a fragmented lunate.

A Treatment Algorithm Based on Cortical Integrity of The Lunate

The key to the management of symptomatic KD lies in determining the integrity of the lunate cortex (►Fig. 1). The lunate is salvageable if the cortex is intact and is not salvageable if the cortex is breached. The possible exception arises and the lunate is salvageable, if there is a coronal split fracture amenable to fixation.[35] Plain radiograph is the primary investigation of choice if carpal pathology is suspected in the evaluation of wrist pain. In the absence of radiographic changes and if KD or other soft tissue pathology is suspected, the wrist is further evaluated by an MRI scan. If there are radiographic changes consistent with KD on plain radiograph, and unless there is clear comminution of the lunate, the lunate is evaluated further with a CT scan to determine its cortical integrity, as fractures of the lunate can occur in Lichtman Stage 1 (►Fig. 2c, d).

Intact Lunate Cortex on Computed Tomography Scan

When the cortex of the lunate is intact on sagittal, coronal, and axial slices on a CT scan, the lunate is salvageable and the lunate is preserved. The cortical integrity can be intact in Lichtman stage II, IIIA, and in Stage IIIB (►Fig. 5). Although the necessity for surgical intervention in these cases is not clear,[36] a lunate unloading procedure with revascularization may be performed depending on surgeon preferences. An MRI scan in these cases may provide insight into the vascular status of the lunate and may also be used to monitor the evolution of the disease; however, interpretation of the MRI in KD would need to be balanced by the uncertainty of its accuracy in determining the vascular status of the lunate.

As the incidence of KD is low, there is poor comparative evidence[8] to support one unloading procedure over another.[22] In an ulnar-negative patient, we prefer radial shortening osteotomy to unload the lunate as it is widely accepted that the increased load through the central column contributes to the collapse of the lunate.[1,7] The biomechanical effect of radial shortening on the lunate[37,38] and the long-term clinical outcomes have been documented.[30,39] This is the most common procedure performed for this group of patients.[40]

In patients with ulnar-neutral or -positive variance, the procedure of choice to unload the lunate is controversial. In a biomechanical study, Kam et al[41] showed a very similar reduction in lunate cortical strain in both radial opening wedge and closing wedge osteotomies. While others prefer

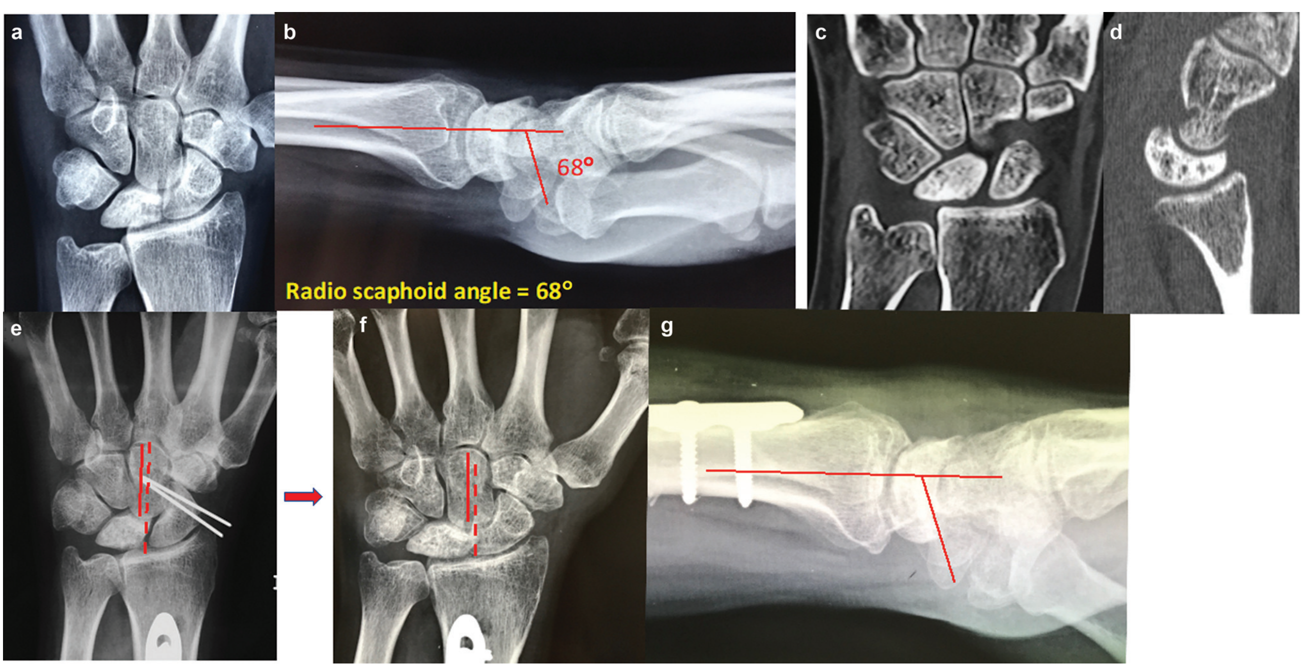

Fig. 5 Lichtman stage IIIB Kienböck's disease. (**a**) Posteroanterior plain radiograph showing a sclerotic lunate. (**b**) Lateral plain radiograph showing a flexed scaphoid of 68 degrees. (**c**) Coronal slice CT scan image showing an intact lunate cortex. (**d**) Sagittal slice CT scan showing an intact lunate cortex. (**e**) Posteroanterior plain radiograph after vessel implantation, radial shortening, and temporary unloading of the lunate with two Kirschner wires. (**f**) and (**g**) Posteroanterior and lateral radiographs at 12-year follow-up.

capitate shortening,[42,43] there are biomechanical studies that report a risk of overloading the midcarpal joint.[37] Our preference is for a closing wedge osteotomy as it lessens the risk of nonunion associated with an opening wedge osteotomy and avoids the risk of midcarpal overload from capitate shortening.

The necessity for revascularization is controversial. It is our practice to routinely revascularize the lunate, as the presumptive cause of KD is ischemia, and there are no reported negative consequences of the procedure. It should be performed based on the surgeons' familiarity, and a pedicled bone graft[17,44] or vessel implantation[16,35] can be used. Temporary Kirschner-wires are placed between the extended scaphoid and capitate to reduce the load through the revascularizing lunate (►**Fig. 5e**). This is based on experimental studies suggesting transient osteomalacia during revascularisation.[20]

When the lunate cortex is intact, the status of the articular cartilage of the wrist and midcarpal joints does not influence the decision-making process, as every effort is made to salvage the lunate. Arthroscopy does not need to be performed in these cases.

Fractured Lunate on Computed Tomography Scan

When fracture and fragmentation of the lunate occurs, the structural integrity is lost and the lunate is no longer salvageable (►**Fig. 3a**). In these cases, an MRI scan of the lunate to assess its vascularity does not add further to the therapeutic decision-making process, as the fragmented lunate cannot be salvaged by revascularization. The treatment here is aimed at either bypassing the lunate (SC or STT arthrodesis) or removing the lunate (PRC, capitate lengthening, or lunate replacement).

We prefer bypassing the lunate in these cases through SC arthrodesis,[45] although there is no evidence to help us choose SC over STT arthrodesis[34,46] or over other available options including PRC and capitate lengthening. Both SC and STT arthrodesis unload the lunocapitate and radiolunate joints, but there is consequent increased loading of the adjacent joints.[47] SC[45,48–50] and STT[51] arthrodesis reestablishes the carpal height by correcting the radioscaphoid angle. There are no significant differences in wrist motion from biomechanical simulation studies.[52] The lunate is, however, not excised as it risks progressive ulnar translocation of the carpus.[3,50,51,53] Based on a recent systematic review, the nonunion rate specifically for KD was reported to be 3.3%.[3,50,51,53] As discussed previously, arthroscopy is unnecessary if a bypassing procedure is the preferred option.

If the preference is to remove the lunate, PRC is a popular treatment option in Lichtman Stage IIIB KD.[54,55] Several clinical studies with long-term follow-up specific to KD have shown favorable results in the range of motion, with a flexion-extension arc of 76 to 105degrees and a radioulnar arc of 41 to 55 degrees and is effective in relieving pain.[56–58] However, there are risks of early onset radiographic radiocapitate joint arthritis.[57,59] If PRC is the preferred treatment option, the status of the proximal articular surface of the capitate and the lunate fossa would need to be assessed by arthroscopy, as a "functional" cartilage in these surfaces is a prerequisite for a successful PRC. However, this decision may also be made intraoperatively by direct inspection of the chondral surface.[3] Other options where there is fragmentation of the lunate include capitate lengthening or its modification[25,60] or lunate replacement.[26]

Less commonly, the proximal articular surface of the lunate alone is fractured or fragmented (►**Fig. 4**). In these cases, if the articular surface of the lunate fossa remained "functional" after arthroscopic assessment, the proximal lunate may be replaced by free vascularized medial femoral trochlear flap.[18] If the joint surface was degenerate, then wrist motion may be preserved by radiolunate or RSL arthrodesis.[28,61]

Discussion

Although the LSB classification provides a comprehensive overview and treatment algorithm for KD, the use of MRI and arthroscopy is not necessary in all cases as it adds unnecessary cost and surgery. The decision on the management options may be made by determining the integrity of the lunate cortex and deciding whether the lunate is salvageable or not by CT scan. The management options then differ. Because of the rarity of the condition and the lack of comparative studies to help us choose the preferred treatment, once the salvageability is determined, the treatment options chosen will be based on the surgeon's personal preference, influence by mentors and the perceived ease of the available options.

Ethical Review
No ethical review required for this special review section.

Conflict of Interest
None declared.

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