Kienböck Disease Classification from Lichtman to Contemporary Approaches

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Abstract

The incidence of Kienböck's disease is about 3 per 100,000 patients, predominantly affects male. There are many classification systems used with this condition. They are radiographic, magnetic resonance, arthroscopic and combined. The main radiographic classification for aseptic necrosis of the lunate, which is used today, is that of D. Lichtman. The main magnetic resonance classification is that of Schmitt, and the most widely used arthroscopic classification is that of Bain and Begg. Regardless of the classification system used, the ultimate goal is the accurate staging of the disease and the determination of an appropriate treatment method. The clinical outcome highly depend on that.

Keywords — Kienböck's disease, Classification, Avascular necrosis of the lunate

1. Introduction

In 1910, the Austrian radiologist Robert Kienböck first described aseptic necrosis of the lunate. The condition most often affects patients between the ages of 20 and 40, predominantly male. The incidence of the disease is about 3 per 100,000 patients. The etiological causes leading to the development of lunate malacia are complex. The clinical picture is characterized by pain, reduced grip strength, and limited dorsiflexion of the wrist. Kienböck's disease is a progressive degenerative disease that, if left untreated, leads to varying degrees of disability. Correct classification of the disease is extremely important for determining the method of treatment and therefore the clinical outcome.

2. Radiographic Classification

2.1 Lichtman's Classification

The main radiographic classification for aseptic necrosis of lunatum used today is that of D. Lichtman. The author describes the development of the results through 4 stages, which are diagnosed on standard radiographs (Fig. 1-2). The classification has been leading in describing the severity of the progression of the achieved for many decades and has developed since its inception, with the first documented version being presented by Stahl in 1947[5]. Initially, there was a radiographic classification consisting

of 4 parts, describing the successive stages of idiopathic avascular lunatomalacia[6]. Later in 1996, P. Dekhu created his own classification, combining the third and fourth stages of Stahl's classification. In 1977, Lichtman modified it in a series of cases of silicone lunate arthroplasties[6]. The author concluded that treatment of the condition detected at an earlier stage leads to better outcomes, and so sought to better define the early and late stages of the disease. He used the information to create his version of the 4-stage classification with the following goals: First, the definition of a preoperative staging system to guide appropriate treatment, and second, the use of this staging system to allow retrospective comparison of outcomes based on different treatments for each stage of the disease[10]. A later version of the classification was published in 1993 by Lichtman et al., with the most recent modification being in 2010, with the addition of stage IIIC. The different phases of Lichtman's modification of the Stahl classification are presented with descriptions of their specific findings and corresponding adaptations over time[10].

Stage One

Standard lunate radiographs usually show normal bone density and architecture, at which point the diagnosis of the disease is presumed based on clinical features (Fig. 2A). Linear or compression fractures of the lunate may not be well defined radiographically. Computed tomography is a useful diagnostic imaging modality because it produces increased radiographic uptake in the lunate in patients with early disease that is not visible on standard radiographs. With the increased availability and availability of magnetic resonance imaging (MRI), it has replaced computed tomography (CT) for early diagnosis of the condition. MRI findings suggestive of aseptic necrosis of the lunate include uniform decreased signal intensity of the lunate on both T1 and T2 sequences, indicative of bone marrow pathology associated with aseptic necrosis[2,7]. Other findings include decreased signal on T1 images with increased T2 signal, indicating bone marrow edema[2]. The uniform signal intensity characteristic of avascular necrosis is a necessary condition for differentiation from ulnocarpal impaction syndrome, the treatment of which is diametrically opposed to that of lunatomalacia. Symptoms in the first stage may include pain that worsens with physical activity and improves with rest, often exacerbated by wrist extension and axial load. The initial stage of the disease is often confused with a wrist sprain. At this stage, immobilization is the main method of treatment[11].

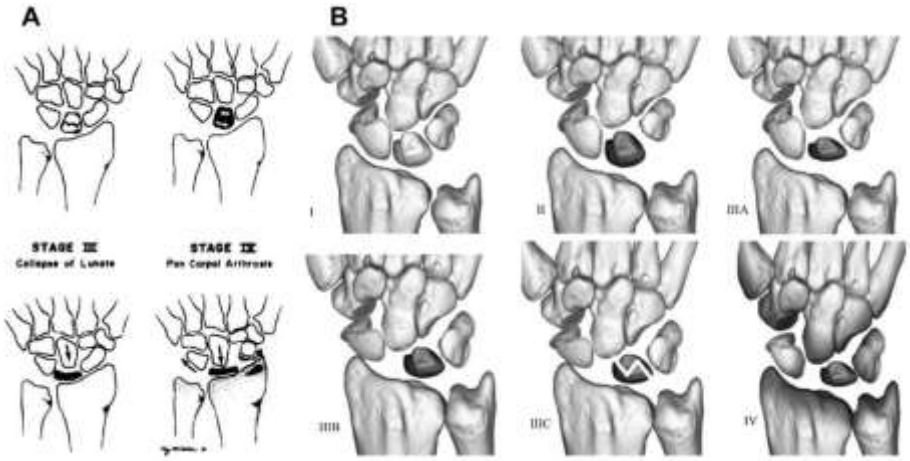


Fig. 1. Lichtmann classification.
(A) Lichtmann's original 4-stage modification of Stahl's classification.Stage I: normal radiographs or non-displaced fracture lines. Stage I: density changes on plain radiographs. Stage III: lunate fragmentation, carpal collapse, with or without the "ring sign" of the flexed scaphoid. Stage IV: additional radiographic evidence of peri-lunate arthrosis.
(B) The modern 6-stage Lichtmann axial radiographic classification.Stage I: normal alignment of the carpal bones, often without radiographic evidence of bony changes. Stage II: sclerosis of the lunate.
Stage IIIA: preserved alignment of the carpal bones, collapse and fragmentation of the lunate (radioscaphoid angle <60°).
Stage IIIB: collapse and fragmentation of the lunate with associated carpal collapse and flexion of the scaphoid axis (radioscaphoid angle ≥60°).
Stage IIIC: associated coronally oriented lunate fracture.
Stage IV: evidence of advanced carpal collapse with peri-lunate carpal arthrosis.([A] From Alexander AH, Turner MA,Alexander CE, Lichtman DM. Lunate silicone replacement arthroplasty in Kienbo¨ ck's disease: a long-term follow-up. J Hand Surg Am. 1990 May;15(3):401-7;8 with permission; and [B] Lichtman DM, Pientka WF 2nd, Bain GI. Kienbo¨ ck Disease: A New Algorithm for the 21st Century. J Wrist Surg. 2017 Feb;6(1):20;

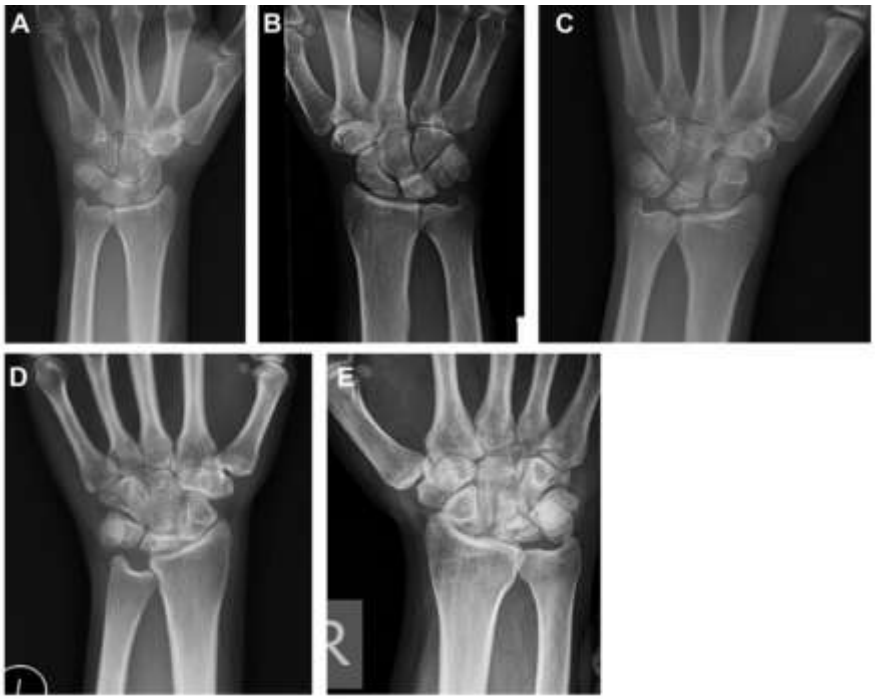


Fig. 2. Radiographs of the Lichtman stages. Stage I – normal radiographs of the left wrist. (B) Stage II – identified sclerosis of the lunate. (C) Stage IIIA – identified by collapse of the lunate without flexion of the scaphoid. (D) Stage IIIB – shows collapse of the lunate with flexion of the scaphoid and the annular sign. (E) Stage IV – collapse of the lunate with pancarpal arthritic changes. (Copyright: A. Lauder MD, Denver, Colorado.)

Stage Two

Stage two is characterized by radiographic changes in the lunate density. Sclerosis and osteolytic changes may be seen, but the architecture of the carpal bones and intercarpal alignment remain intact. Clinically, swelling, nocturnal pain, and other symptoms characteristic of synovitis may be present. Treatment of stage II has historically included lunate decompression or revascularization techniques[11].

Stage Three

In 1982, D. Lichtman revised and subdivided this stage into 2 substages - IIIA and IIIB, depending on the presence of collapse of the lunate with normal alignment of the scaphoid (IIIA) or fixed flexion of the scaphoid (IIIB). Differentiation between these 2 substages is essential for determining the type of treatment. The clinical picture is dominated by pain both during physical activity and at rest, and progressive mechanical symptoms, including locking or cracking, may be observed as the severity of the disease progresses. In the original version of the classification, stage three did not have 2 subgroups and is described as lunate collapse, proximal capitate migration, and carpal architecture disruption. In Lichtmann's early cases, patients in stage three of the disease often did worse and had unpredictable surgical outcomes compared to patients in other stages. [2] The uncertainty of the results led to further analysis

showing that lunate collapse and capitate migration are not simultaneous events[2].On standard radiographs, stage IIIA shows fragmentation and collapse of the lunate without changes in the alignment of the carpal bones. Stage IIIB is characterized by fragmentation and collapse of the lunate with associated carpal bone discrepancy, described as fixed flexion of the scaphoid. Scaphoid flexion was originally identified by the presence of a "ring sign" on the scaphoid, visible on anteroposterior radiographs. The ring sign represents flexion of the distal pole of the scaphoid, in the facet view, as it sits perpendicular to the long axis of the radius. As the disease progresses, stage IIIB may also involve proximal migration of the capitate, representing collapse of the carpal bones[8]. The distinction between stages IIIA and IIIB is of great importance for treatment planning. Treatment of stages I through IIIA involves revascularization and relief of the lunate by joint leveling procedures. In stage IIIB disease, the carpal bones are not aligned, and the associated carpal instability usually requires reconstructive or salvage procedures[11]. Distinguishing between stages IIIA and IIIB is not an easy task. Condi and colleagues retrospectively analyzed 75 patients treated for lunate malacia over a 10-year period at a single institution[9]. Their team used a wrist outcome scale that assessed functional limitations, changes in range of motion, and strength compared with the unaffected hand. A score of "poor" was assigned if the patient underwent wrist arthrodesis. The authors analyzed changes in carpal alignment using lunate index, wrist height index, "ulna-variant," scapholunate angle (SL), and radioscaphoid angle (RS). Regardless of the treatment modality used, the only measure that significantly correlated with outcome was the preoperative radioscaphoid angle, with a larger RS angle corresponding to a worse outcome ($P < 0.001$) (Fig. 3). In the subgroup of patients treated with joint-leveling operative techniques, an RS angle greater than 60 degrees did not lead to good or excellent outcomes[9]. The treatment algorithm at that time focused on the presence or absence of lunate collapse. These results helped define subgroups of stage III disease. The measurement of the RS angle is not dependent on the lunate deformity, but rather represents the presence of scaphoid flexion and carpal instability. The authors recommended using an RS angle of 60° as the threshold separating Lichtmann stages IIIA and IIIB.[9]

Stage Four

The final, fourth stage of lunatomalacia is characterized by collapse of the lunate with accompanying degenerative arthrosis of the radiocarpal and/or midcarpal joints. The clinical presentation includes pain and stiffness, which is characteristic of advanced degenerative arthrosis. Radiographically, the arthritic changes that are seen are often very similar to the advanced collapse seen in advanced scapholunate collapse. For purposes of comparison, stage four is sometimes also referred to as advanced collapse in avascular necrosis of the lunate[2].

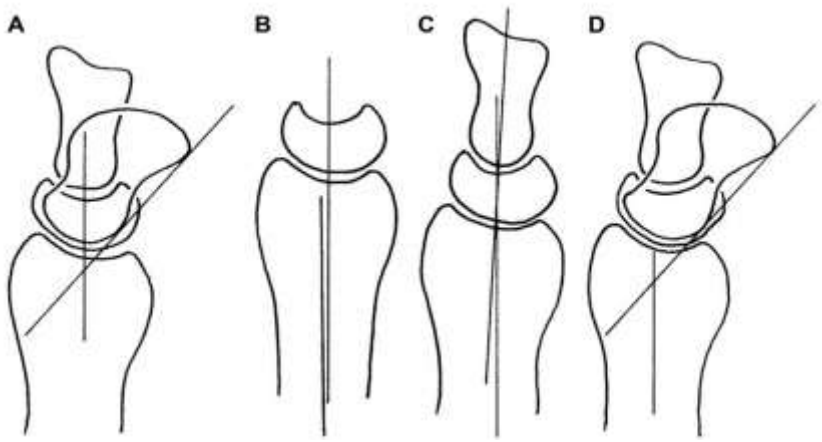


Fig. 3. Carpal alignment measurements used in the assessment of Kienböck's disease.

(A) Scapholunate angle (SL). The scaphoid axis is represented by a line drawn tangent to the dorsal and volar proximal and distal borders of the scaphoid. The lunate axis is represented by a line drawn perpendicular to the tangent connecting the volar and dorsal distal poles of the lunate.
(B) Radiolunate angle. The line representing the radius is drawn through the center of the radius at 2 and 5 centimeters proximal to the joint. The lunate axis is represented by a line drawn perpendicular to the tangent connecting the volar and dorsal distal poles of the lunate.
(C) Radiocapitate angle. The line representing the radius is drawn through the center of the radius 2 and 5 cm proximal to the joint. The capitate is represented by a line through its proximal and distal poles.
(D) Radioscophioid angle (RS). The line representing the radius is drawn through the center of the radius 2 and 5 cm proximal to the joint. The scaphoid line is drawn as a tangent to the volar proximal and distal borders of the scaphoid. An angle of 60° or greater, which represents fixed flexion of the scaphoid, distinguishes Lichtmann stages IIIA from IIIB.
(Copyright: Charles A. Goldfarb, J. Hsu, Robert H. Gelberman, Mark I. Boyer. The Lichtman classification for Kienböck disease: an assessment of reliability. Journal of Surgery of the Hand - American Edition), January 2003; Volume 28, Issue 1: 74–80.

2.2 Swanson classification

Swanson used standard radiographs to divide Kienböck's disease into 6 stages of progression to outline the severity of the disease, similar to the Lichtman classification. In 1985, Swanson and colleagues retrospectively reviewed 42 cases of silicone prosthesis implantation in patients with the disease[2]. The 6-stage system was developed based on the severity of bony changes in the lunate and surrounding carpal bones, as well as factors such as scaphoid rotation and carpal collapse. This classification describes radiographic findings and treatment options. The stages of this classification correspond to an expanded description of disease progression that correlates with the analogous stages of Lichtman's classification II to IV. Their retrospective study highlighted the association between worsening avascular necrosis of the lunate and collapse in carpal height, increasing RS angle, and ulnar migration of the capitate.[13] This system did not become widely accepted because of its association with silicone arthroplasty, a procedure that was abandoned due to its high complication and failure rates. However, Swanson's use of the RS angle was useful for subsequent work by Lichtman, Condy, Goldfarb, and others[1].

3. Magnetic Resonance Imaging Classification

3.1 Schmitt Classification

With the increasing availability and usability of MRI, several classifications have emerged that use MRI as the diagnostic test of choice. Table 2 summarizes the Schmitt 3-level classification and specifically highlights the geographic areas of the lunate on T1, T2, and contrast-enhanced T1 images. Schmidt et al. evaluated changes in the lunate using contrast-enhanced MRI[17]. The study showed that gadopentetate contrast in the presence of preserved perfusion increased intraosseous signal intensity on T1 images. Pathoanatomical features define ischemia in 3 predictable zones: A necrotic zone, often at the proximal pole of the lunate without enhancement; An intermediate hypervascular zone of recovery with microscopic elements of recycling and repair; And a normal zone of vitality, often at the distal pole with preserved perfusion. After evaluating MRI images of 28 patients with lunatomalacia, 3 distinct stages of ischemia were identified, ranging from (A) edema with intact perfusion to (B) partially necrotic based on the area of perfusion (proximal, mid, or distal), and finally (C) necrotic with poor viability. The authors noted that the evaluation may be complicated in long-term cases of Kienböck disease, which may result in an enhancing synovial reaction after contrast administration[18]. The addition of contrast was found to be most useful in distinguishing between intercellular (reversible) edema and intracellular (irreversible) edema. Without contrast, T2 signal intensity was similar in necrotic, reparative, and normal bone marrow tissue[17]. Furthermore, T1 sequences were found to overestimate osteonecrosis, as both repair and necrosis can be isointense. The use of gadolinium contrast can improve sensitivity and distinguish reversible ischemia from irreversible necrosis[19]. Although the Schmidt classification characterizes the lunate in considerable detail, the classification does not guide treatment decisions for aseptic necrosis of the lunate.

3.2 Nakamura Classification

In 1993, Tsuge and Nakamura studied 24 patients with lunate malacia to analyze the effects of radial shortening compared with radial wedge osteotomy. According to Lichtman's classification, the patients were distributed as follows: 1 patient in stage I, 9 in stage II, 8 in stage III, and 6 in stage IV[14]. MRI scans were performed preoperatively and postoperatively in all patients to monitor healing and revascularization of the lunate. A 5-grade system was established to grade the signal intensity of the lunate on T1- and T2-weighted images (Table 3). The study found increased signal intensity in 18 of 19 patients who underwent radial osteotomy 1 year after surgery. Interestingly, the majority of these showed improvement only in T2 signal, with overall T2 images showing earlier recovery of signal intensity compared with T1 images, indicating that T2 images are more sensitive to vascular changes in the lunate.[14] These findings have been confirmed by other investigators, who also concluded that signal intensity increases with bone repair[15,16]. This classification has not been widely adopted because it does not guide treatment choices at different stages. However, the work has helped to inform the diagnostic and prognostic use of MRI in Kienböck's disease. In addition, the system does not require the use of intravenous gadolinium contrast and may allow assessment of lunate revascularization after surgical intervention[1].

4. Arthroscopic Classification

4.1 Bain and Begg

The Bain and Begg arthroscopic classification system describes the functional status of the interarticular articular surfaces adjacent to the lunate (Fig. 4)[3]. Kienböck's disease usually begins initially with arthritic changes on the proximal articular surface of the lunate with secondary changes in the lunate facet of the distal radius. As the arthritic changes in lunatomalacia progress, the distal surface of the lunate and eventually the proximal part of the capitate become involved. Thus, the Bain and Begg classification system with its five stages reflects this progression of joint degeneration, while also aiming to guide surgical treatment according to the number of articular surfaces involved. In 2006, Bain and Begg described their approach using arthroscopy to assess and classify the disease. In their description, wrist arthroscopy, performed in a standard manner, allowed for the identification of synovitis and assessment of the articular surfaces located near the lunate. The authors believe that arthroscopy provides both a diagnostic tool and a guide for definitive surgery based on intraoperative findings[3]. When the articular surfaces are considered functional, procedures such as synovectomy, decompression, revascularization, or decompression procedures may be applied. When the articular surfaces are nonfunctional, with cracks, loss of articular surface, or fracture, reconstructive or salvage procedures such as proximal carpectomy, radiocapitulolunate arthrodesis, or wrist arthrodesis may be performed, depending on the extent of joint damage. The classification is well accepted because it reflects the progressive development of arthritis, providing treatment options at each stage. In addition, advanced imaging studies such as magnetic resonance imaging (MRI) or computed tomography (CT) can be used instead of arthroscopy to determine the condition of the articular surfaces[23].



Figure 4. The Bain and Begg classification of Kienböck disease based on the number of nonfunctional articular surfaces. (Copyright: Bain B., Begg M. Arthroscopic evaluation and classification of Kienböck disease. Techniques in Hand and Upper Limb Surgery. 10:8, 2006.*[22]

5. COMBINED CLASSIFICATION

The most recent classification system was developed in 2017. It is a combined system that combines several existing classifications to better guide diagnosis and

treatment (Fig. 5). By taking into account the patient's age, the potential for lunate revascularization, and individual carpal pathoanatomical characteristics, the combined classification simplifies many useful existing schemes. Lichtman and Bain divided the algorithm into three sections: (A) age, (B) lunate stage, and (C) wrist condition[4].

Section (A) divides patients into 3 age subgroups with the potential for good results from nonoperative treatment: under 15 years, 16 to 20 years, and over 70 years. Patients between 21 and 70 years of age are analyzed separately in sections (B) and (C), and surgical approaches are discussed. Section (B) is subdivided into 3 parts that assess the integrity of the lunate and offer appropriate treatment recommendations. Section (C) is divided into 4 subgroups depending on the degree of joint damage and carpal collapse[4].

6. Conclusion

There are many classification systems used in Kienböck's disease. They are radiographic, magnetic resonance, arthroscopic and combined. The main radiographic classification for aseptic necrosis of the lunate, which is used today, is that of D. Lichtman. The main magnetic resonance classification is that of Schmitt, and the most widely used arthroscopic classification is that of Bain and Begg. Regardless of the classification system used, the ultimate goal is the accurate staging of the disease and the determination of an appropriate treatment method.

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