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REVIEW ARTICLE

DIAGNOSTIC METHODS IN KIENBOCK DISEASE

METODY DIAGNOSTYCZNE W CHOROBIE KIENBOCKA

Katarzyna Kopcik
Medical University of Silesia in Katowice, School of Medical Sciences in Zabrze, Poland

ABSTRACT

Introduction

Kienbock disease is relatively rare condition of aseptic necrosis of the lunate, which can be diagnosed using X-ray scans, CT scans, MRI scans and diagnostic arthroscopy.

Aim

Main aim of the paper is to sum up available knowledge of diagnostic methods of Kienbock disease with staging classifications.

Material and methods

The paper is based on academic literature and scientific publications, which are available in PubMed database. After evaluation of article's abstracts, articles were selected and analysed with the references citated.

Conclusions

There are different methods of radiological diagnostics of Kienbock disease. MRI scans and diagnostic arthroscopy appear to be the most detailed techniques, but X-ray scan should be ordered as primary radiological examination during diagnostic process. Ultrasonography is not useful while searching for a diagnosis.

Keywords: Kienbock disease, osteonecrosis, orthopaedics, radiological diagnostics

STRESZCZENIE

Wstęp

Choroba Kienbocka jest stosunkowo rzadko występującą jałową martwicą kości księżycowatej, która może zostać zdiagnozowana przy użyciu RTG, tomografii komputerowej, rezonansu magnetycznego i diagnostycznej artroskopii nadgarstka.

Cel

Głównym celem pracy jest podsumowanie dostępnej wiedzy na temat metod diagnostycznych w chorobie Kienbocka oraz przedstawienie istniejących klasyfikacji zaawansowania choroby.

Materiał i metody

Pracę przygotowano w oparciu o literaturę naukową i publikacje naukowe dostępne w bazie PubMed. Po wstępnej ocenie abstraktów artykułów, wybrano i przeanalizowano publikacje odpowiadające tematyce poniższego podsumowania, wraz z cytowanymi źródłami.

Author responsible for correspondence:
Katarzyna Kopcik
Medical University of Silesia in Katowice,
School of Medical Sciences in Zabrze, Poland
Email: kopcik.katarzyna1@gmail.com
https://orcid.org/0000-0003-0815-4752

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Wnioski
Istnieją różne sposoby diagnostyki radiologicznej choroby Kienbocka. Rezonans magnetyczny i diagnostyczna artroskopia wydają się być najbardziej dokładnymi technikami, jednak zdjęcia RTG powinny być zlecane jako pierwsze podczas procesu diagnostycznego analizowanej choroby. Ultrasonografia nie znajduje zastosowania podczas diagnostyki.

Słowa kluczowe: choroba Kienbocka, martwica kości, ortopedia, diagnostyka radiologiczna

Introduction
Kienbock disease (KD) appears as aseptic necrosis of the lunate, although its origin is still unclear. Before the osteonecrosis theory being popularized, it was considered as osteomalacy or a result of repetitive microtrauma (Camus *et al.* 2021, Camus *et al.* 2022, Cross *et al.* 2014). Other causes of the disease being regarded are morphological, vascular, infective, genetically acquired or systemic (Golay *et al.* 2016). Kienbock disease is relatively rare – radiological prevalence was measured by Golay *et al.* as 0.0066% – the study analysed over 150 000 radiographs (Golay *et al.* 2016). Typical patient with Kienbock disease is a 20 to 40 years old male labourer (Camus *et al.* 2022). Among potential symptoms, one can distinguish pain in the dorsal part of wrist, stiffness of the wrist, swelling of the wrist area, reduction of mobility and grip strength of the hand (Nowakowski, Mazurek 2017). Kienbock disease is usually diagnosed after classic radiology evaluation (Nowakowski, Mazurek 2017). Nowadays, the MRI scans of the wrist are also used during diagnostic process (Fontaine 2016) When searching for a lunate fracture or necrosis areas – CT scans can be used (Fontaine 2016). Another option to visualise lunate is diagnostic arthroscopy (Bain *et al.* 2016). Treatment methods include immobilization (especially regarding young patients and early stages of a disease) and surgical procedures, including osteotomies and arthroplasties. In some cases, vascularized bone graft is implemented to improve blood circulation of a lunate (Nowakowski, Mazurek 2017, Nealey *et al.* 2018).

Anatomy of the lunate
Lunate is a moon-shaped carpal bone, located in its proximal row. It plays an important role in transferring loads though the middle column of the wrist (Fontaine 2016). Lunate, being a small bone, has four articular surfaces (Camus *et al.* 2022, Fontaine 2016): **proximally** – for the carpal surface of the radius and triangular fibrocartillage complex, **laterally** – for the proximal side of the scaphoid, **medially** – for the triquetrum and **distally** – laterally for the head of the capitate, medially for the top of the hamate.

Lunate has two non-articicular facets: dorsal – anterior surface and palmar – posterior surface (Fontaine 2016). When describing morphological types of lunates, one can name Viegas-type, and Zapico-type (MacLean *et al.* 2022).

Viegas-type lunates can be divided into type 1 and type 2, which differs in the ways of transferring loads. Type 1 is more common when analysing patients with Kienbock disease. This type of lunate tend not to have articular surfaces with the hamate – the only facet is for the capitate. They mostly load through mid-carpal joint. On the other hand, type 2 lunates, which has facets for both hamate and capitate, tend to transfer loads through radiocarpal joint. The path of transferring loads in type 1 may increase pliancy for a stress fracture of the lunate (MacLean *et al.* 2022, Lamas *et al.* 2007).

Zapico divided lunates into three types (Camus *et al.* 2022, MacLean *et al.* 2022, Lamas *et al.* 2007). Type 1 is described as more trapezoidal and more receptive to develop Kienbock disease. Type 2 tend to look more like

square, while type 3 has a proximal surface divided into two facets.

Lunate's blood supply comes from radial and anterior interosseus arteries Nutrient vessels reach the lunate from both dorsal and volar surfaces (Fontaine 2016, MacLean *et al.* 2022, Lamas *et al.* 2007).

Kienbock disease

The cause of Kienbock disease is still unknown, but, according to most authors, it tends to be aseptic necrosis of the lunate (Camus *et al.* 2021). It mostly affects dominant hand of the young male manual labourers (Nealey *et al.* 2018, Daly *et al.* 2022). The main symptoms include pain of dorsal side of the wrist, swelling, limited range of hand and wrist motion, feeling of wrist stiffness and reduced grip strength of the hand (Nowakowski, Mazurek 2017, Daly *et al.* 2022). Wrist pain usually increase while performing forceful wrist extensions (Fontaine 2016). When describing potential causes of Kienbock disease, one can list traumatic and non-traumatic factors. Among traumatic factors, vascular system trauma, osseus system trauma and vascular nervous system trauma can be distinguished. Non-traumatic causes include vasculitis, embolus of the vessels or steroid treatment, which may lead to lunate aseptic necrosis (Lamas *et al.* 2010).

When analysing osseus system trauma factor, also known as fracture theory, way of transferring loads through the carpal bones should be taken under evaluation. The path of load transmission, described above, can vary in different anatomical types. Lunate types, such as Viegas-type 1 and Zapico-type 1 are considered to be more susceptible to develop KD due to force transfer conducting to overload of the lunate. It may lead to compression fractures of the lunate or ligament ruptures, and these conditions may result in Kienbock disease (Lamas *et al.* 2010).

Currently, it is believed that repetitive microtrauma or acute trauma are no longer considered as main factors of Kienbock disease. KD seems to be more linked with non-traumatic vascular risk factors (Fontaine 2016).

Radiological diagnostics

a. X-ray scans

Classic radiology is the initial method to visualize Kienbock disease (Camus *et al.* 2022, Lichtman *et al.* 2016, Lichtman *et al.* 2017). When examining a patient suspected of Kienbock disease, one should evaluate standard posteroanterior and lateral X-ray scans of patient's wrist. Classic radiographs in early stages of the disease are often negative. KD tend to progress, so in more advanced stages of the disease X-ray scans can present increased bone density of the lunate. This image is typical for osteonecrosis (Cross *et al.* 2014). With progression of the disease, images like lunate collapse, lunate fracture can be distinguished (Camus *et al.* 2021, Camus *et al.* 2022, Cross *et al.* 2014, Fontaine 2016, Nealey *et al.* 2018).

While evaluating X-ray scans, one can divide cases according to different classification systems. Historically, staging guidelines implemented by Stahl, Decoloux and Razemon was used (Cross *et al.* 2014, Fontaine 2016). Currently, physicians and scientists are widely using Lichtman classification of KD, modified in 1993 (Camus *et al.* 2021, Camus *et al.* 2022, Fontaine 2016, Nealey *et al.* 2018). Stage IIIC, which corresponds with lunate fracture, was first introduced in 2010 as an addition to modified scheme (Nealey *et al.* 2018):

- **stage 0** – normal X-rays with temporary wrist pain;
- **stage I** – normal X-rays with constant wrist pain;
- **stage II** – lunate sclerosis recognizable in X-ray scan, but the bone's anatomy is normal;
- **stage III** – anatomical modifications of lunate due to Kienbock disease:
  - IIIA – lunate collapse, but with carpal height preserved;
  - IIIB – lunate collapse coexisting with carpal collapse;
  - IIIC – lunate fracture;

- **stage IV** – advanced wrist osteoarthritis or advanced carpal collapse (Kienbock Disease Advanced Collapse – KDAC).

b. Ultrasonography

According to available sources, ultrasonography is not used when diagnosing Kienbock disease.

c. CT scans

Imaging methods like CT provide better visualization of bone anatomy, so it may conduct to more detailed lunate examination, resulting in better staging of the disease and more accurate surgery planning (Daly *et al.* 2022, Arnaiz *et al.* 2014). CT scans may reveal lunate fractures or collapse, and the image is more relevant that X-ray scan (Fontaine 2016, Daly *et al.* 2022). It is useful when imaging more advanced stages of KD (Arnaiz *et al.* 2014), and it is applicable when characterizing lunate necrosis, sclerosis, bone fragmentation or collapse. So far, there are no classification systems based on CT scan results.

d. MRI scans

MRI scans provide detailed picture of lunate's area and of wrist as a whole, while being non-invasive method, which is not bearing risk of X-ray exposure. Nowadays, MRI scans are widely available and can enrich diagnostic process of Kienbock disease. Its advantages include possibility to visualize intraosseous oedema in early stages of KD and to differentiate necrosis, oedema, and vascularization areas due to gadolinium injections, what is impossible when estimating X-ray scans. It also allows to evaluate cartilage condition (Camus *et al.* 2021, Camus *et al.* 2022). MRI scans are also applicable when X-ray scans are negative in early stages of Kienbock disease.

Both T1-weighted FSE and T2-weighted FSE are used (Lichtman *et al.* 2017). In T1-weighted scan normal bone marrow will have high T1 signal, according to the fact, that marrow contains fat. T1 signal is low when neovascularization, oedema, bone necrosis is present (Fontaine 2016, Lichtman *et al.* 2017).

In T2-weighted images, regular marrow, which contains reduced amount of water, has a low signal. When ischaemia occurs, marrow present high signal in T2 scan. Necrosis, due to low water contains, is also presenting low signal (Lichtman *et al.* 2017).

When evaluating MRI scans of wrist, one can distinguish **type N** – corresponding with normal signal of a lunate, **type A** – corresponding with vascular stasis with ischaemia, prognosis is described as good, **type B** – corresponding with oedema and necrosis zones, with intermediate prognosis, and **type C** – corresponding with total necrosis of lunate, with poor prognosis, according to Schmitt (Camus *et al.* 2021, Camus *et al.* 2022, Lichtman *et al.* 2017, Lichtman *et al.* 2016).

e. Arthroscopy

Diagnostic arthroscopy in Kienbock disease can be used to evaluate condition of cartilages or ligaments, that are not apparent on classic radiographs (Camus *et al.* 2022, Daly *et al.* 2022). Working portals to insert tourniquets and to perform arthroscopic procedures are mostly implemented in radiocarpal, midcarpal (radial or ulnar) joints (Bain *et al.* 2016). Normal cartilage is visible in arthroscopy as firm, white and smooth (Wagner *et al.* 2022). During diagnostic arthroscopy, the lunate and its chondral surfaces can be carefully examined – this method is useful when visualizing chondral damage, flaps, degeneration and other defects, bone fractures, bone fragmentation or synovitis (Daly *et al.* 2022, MacLean *et al.* 2017, Wagner *et al.* 2022, Lockwood *et al.* 2022). Degeneration of lunate area may also include chondral sclerosis, fissuring, tissue loss – local or extensive (Wagner *et al.* 2022). The wide array of structures and potential damages that can be visualized in arthroscopy made this method a primary tool while diagnosing KD (Bayoumy *et al.* 2015).

A scheme used to describe cases of Kienbock disease is Bain and Begg system, first implemented in 2006. This classification bases on number of non-functional articular surfaces of the lunate, which are not

distinguishable on radiography scans includes **grade 0** – none of lunate's articular surfaces is non-functional, **grade 1** – one non-functional surface – proximal lunate facet, **grade 2a** – two non-functional surfaces – proximal lunate and lunate surface of radius, **grade 2b** – two non-functional surfaces – proximal and distal lunate, **grade 3** – three non-functional surfaces – capitate facet is usually normal, and **grade 4** – all four articular surfaces are non-functional (Camus *et al.* 2022, Nealey *et al.* 2018, Daly *et al.* 2022, Lichtman *et al.* 2016, Wagner *et al.* 2022, Bayoumy *et al.* 2015).

Arthroscopy is the most invasive procedure in diagnostic process, but on the other hand, it provides the most detailed picture of lunate area. It should be considered not only as a diagnostic method, but also as a direction to surgical management based on findings during the examination – including synovectomy, revascularization, decompression, or lunate unloading (Lockwood *et al.* 2022). It is worth mentioning, that there is a significant dissimilarity between radiological evaluation results and arthroscopy picture – it was reported to be poorly correlated (Bayoumy *et al.* 2015).

f. Integrated classification – new algorithm

In 2017 Lichtman *et al.* suggested new algorithm regarding stages and potential management of Kienbock disease (Lichtman *et al.* 2017, MacLean *et al.* 2017, Lockwood *et al.* 2022). Unlike previous staging classifications, it takes under consideration patient's age. Other factors are state of the lunate and of the wrist (Lichtman *et al.* 2017).

Patient's age: patients younger than 15 years are considered as non-operative, patients between 16 and 20 years old are primarily treated conservatively, and surgical unloading of the lunate should be taken under consideration when symptoms are present for more than 3 months. Patients older than 70 years are also primarily non-operative, with synovectomy or more advanced methods being considered and suggested after 6 moths of persistent symptoms (Lichtman *et al.* 2017). Patients between 21 and 71 years old cases are evaluated in points B and C, and the main treatment method in this subgroup is surgery (Lockwood *et al.* 2022).

Stage of the lunate: B1 – lunate intact; (comparable to Lichtman 0, I, II; Schmitt A; Bain 0), B2 – lunate compromised; (Lichtman IIIA; Schmitt B; Bain 1), and B3 – lunate not reconstruable (Lichtman IIIC; Schmitt C; Bain 2b).

State of the wrist: C1 – central column articulations compromised, C1a – radiolunate articulation compromised (Lichtman IIIA; Schmitt B; Bain 2a), C1b – radiolumate and midcarpal articulations compromised (Lichtman IIIA or IIIC; Schmitt B; Bain 3 or 4), C2 – carpal collapse with intact radioscaphoid articulation (Lichtman IIIB or IIIC; Schmitt B; Bain 2 to 4), and C3 – wrist not reconstruable (Lichtman IV; Schmitt C; Bain 4).

Treatment methods

The main goals of managing KD include revascularization of lunate and unloading the lunate to help regaining its original morphology. It should lead to improve patient's functionality of the wrist (range of motion, grip strength) with significant pain reduction (Fontaine 2016).

When choosing treatment methods of Kienbock disease, physicians are usually basing on the severity of the disease (Cross *et al.* 2014).

Stage I, according to Lichtman classification, is usually managed with cast immobilization of wrist for 3 months. If it is not leading to symptoms reduction, methods applicable to stages II and IIIA should be taken under consideration (Cross *et al.* 2014, Lichtman *et al.* 2017).

Stage II and IIIA treatment depends on ulnar variant. Ulnar negative variant therapy has a main aim in reducing pressure on the lunate and unloading the intracarpal area. Decompressing may affect in revascularization of lunate. Procedures leading to lunate unloading and redistribution of carpal pressure are radial shortening osteotomies and ulnar lengthening (Camus *et al.* 2021, Cross

et al. 2014). Ulnar neutral and positive variant treatment methods are vascularized grafts, or osteotomies as an alternative (Cross *et al.* 2014, Lichtman *et al.* 2017). Stage IIIB management is mostly based on surgical methods – proximal row carpectomy (PRC), intracarpal arthrodesis in scaphotrapeziotrapezoidal (STT) or scaphocapitate (SC) joint, radial shortening osteotomy (Cross *et al.* 2014).

Stages IIIA and IIIB can be also managed by lunate reconstruction with pedicled or vascularized cortico-cancellous graft – mainly from distal radius. Other options are femoral condyle, pisiform or iliac bone (Camus *et al.* 2021, Camus *et al.* 2022).

Stage IV treatment options include PRC, partial wrist fusion with lunatectomy or wrist arthroplasty (Camus *et al.* 2021, Cross *et al.* 2014). The arthroplasty contains replacement of damaged articular surfaces of distal radius and proximal carpal row. Another method, combining resurfacing of the above, also could be taken under consideration. Lunatectomy with replacing the lunate with silicone, metallic bodies, autogenic tendon lead to inconsistent and not rewarding outcomes (Daly *et al.* 2022). Wrist denervation is a method leading to pain reduction, but radiographic presentation of the disease is revealing continuous degeneration of the bone (Camus *et al.* 2022, Cross *et al.* 2014, Lichtman *et al.* 2017).

Summary

Kienbock disease is described as aseptic necrosis of the lunate, but its exact origin is still unknown. The condition's symptoms are wrist pain on a dorsal side, wrist stiffness and swelling, loss of motion range and reduction of grip strength. It mostly affects dominant limb of young male manual laborers.

Diagnostic methods include X-ray scans, CT scans, MRI scans and diagnostic arthroscopy. Ultrasonography is not considered useful during diagnostic process, according to the sources – it was not included in analysed studies. Classic radiography appears to be a primary method in the process of recognizing KD. PA and lateral presentations are used to visualize bone necrosis or morphology changes of the lunate. CT scans provide more detailed picture of the lunate, including anatomy, necrosis, bone fragmentation and subtle fractures. It is more applicable to advanced stages of the disease and may also reveal lunar or carpal collapse. MRI scans, including T1 and T2 images, may be considered as second method of scanning the wrist, while searching for the accurate cause of the wrist pain. This method is able to visualize oedema, vascularization, necrosis and cartilage condition. Comparing to X-ray scans and CT scans, MRI appears to be significantly more detailed and useful procedure when diagnosing Kienbock disease. The most invasive method, but also including evaluation of functional aspect of the disease, is diagnostic arthroscopy. It is mainly implemented to carefully examine chondral surface of the lunate area and to evaluate function of lunate's articular facets.

When planning the treatment, staging of the disease is needed. There are different classifications – Lichtman's based on X-ray appearance of the lunate; Schmitt's based on vascularization picture in MRI scan and Bain's – regarding number of non-functional articular surfaces of the lunate, evaluated during arthroscopy. Currently three classifications were put together, and in 2017 the new staging algorithm was implemented – opposite to previous staging guidelines, it respects patient's age when choosing right management method.

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