International Orthopaedics (2019) 43:1089–1095
https://doi.org/10.1007/s00264-018-4018-4

REVIEW ARTICLE

Classification systems of hip osteonecrosis: an updated review

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Received: 21 May 2018 / Accepted: 4 June 2018 / Published online: 18 June 2018

Abstract

Purpose Osteonecrosis of the femoral head (ONFH) typically impacts middle-aged patients who are typically more active and in whom many surgeons would try to delay performing a total hip arthroplasty (THA). This poses a clinical decision-making challenge. Therefore, several options for joint preservation have been advocated, but varying indications and success rates have led to debate on when to use the various procedures. This is due in part to the lack of a generalized system for assessing ONFH, as well as the absence of a standardized method of data collection for patient stratification. Due to the paucity of studies, in this review, we aimed to provide an up-to-date review of the most widely utilized classification systems and discuss the characteristics of each system.

Methods A comprehensive literature review was conducted. Studies published between January 1st, 1975 and March 1st, 2018 were reviewed. The following key words were used in combination with Boolean operators AND or OR for the literature search: "osteonecrosis," "avascular necrosis," "hip," "femoral head," "classification," "reliability," and "validity." We defined the inclusion criteria for qualifying studies for this review as follows: (1) studies that reported on the classification systems for hip osteonecrosis, (2) studies that reported on the inter-observer reliability of the classification systems, and (3) studies that reported on the intra-observer reliability of any ONFH classification systems. In addition, we employed the following exclusion criteria: (1) studies that assessed classification systems for traumatic osteonecrosis, (2) Legg-Calvé-Perthes disease, or (3) Developmental Dysplasia of the Hip. Additionally, we excluded case reports and duplicate studies among searched databases.

Results The following classification systems were the most commonly utilized: The Ficat and Arlet, Steinberg, the Association Research Circulation Osseous (ARCO), and the Japanese Investigation Committee (JIC) classification systems. The details of each system have been discussed and their inter- and intra-observer reliability has been compared.

Conclusion To this date, there is a lack of consensus on a universal and comprehensive system, and the use of any of the previous classification systems is a matter of dealer's choice. The Ficat and Arlet system was the earliest yet remains the most widely utilized system. Newer classification systems have been developed and some such as the JIC shows promising prognostic value while maintaining simplicity. However, larger validating studies are needed. While all of these systems have their strengths, the lack of a unified classification and staging system is still a problem in the diagnosis and prognosis ONFH. Further multi-center collaborative efforts among osteonecrosis experts are needed to adopt a universal classification system that may positively reflect on patient's outcomes.

Keywords Osteonecrosis of the femoral head · Total hip arthroplasty · Decision-making challenge · Classification systems

Introduction

Osteonecrosis of the femoral head (ONFH) is a multifactorial and potentially destructive joint disease that is estimated to affect up to 20,000 people in the USA per year [1, 2]. It typically impacts middle-aged patients who are typically more active and in whom many surgeons would try to delay performing a total hip arthroplasty (THA), which pose a clinical decision-making challenge [3–6]. Therefore, several options for joint preservation have been advocated, but varying indications and success rates have led to debate on when to use the various procedures [7–10]. This is due in part to the lack of a generalized system for assessing ONFH, as well as the absence of a standardized method of data collection for patient stratification [11–14]. Without a universally accepted

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classification system and data collection method, analysis and comparison of patients are problematic and lead to difficulties evaluating disease progression and staging.

Several ONFH classification systems have been described and used at varying rates [12]. Currently, the most commonly used systems include the Ficat [1], the Steinberg [15], the Association Research Circulation Osseous (ARCO) [16], and the Japanese Investigation Committee (JIC) systems [17]. Several other classifications systems, such as Kerboul et al. [18], have been less commonly used. Each assesses a slightly different criterion in the evaluation of ONFH. While the Ficat system uses plain radiographs to determine the stage and progression of disease [1], Steinberg combined radiographs and magnetic resonance imaging (MRI) to stratify the size of the lesion [15]. The ARCO system improved on the Ficat model by incorporating radiographs, computed tomography (CT), MRI, and scintigraphy to determine the size and location of necrotic area [16]. The JIC, which has been adopted by the Japanese Ministry of Health, Labor and Welfare (JMHLW), utilizes T1-weighted MRI to classify osteonecrosis based on the location of the necrotic lesion [17].

Classification systems provide the orthopedic surgeon with the ability to stratify this clinically challenging disease according to severity, prognosis, and indications for different treatment options. Therefore, in this review, we aimed to discuss (1) the most commonly utilized systems and (2) important factors to consider in each.

Methods

Literature search

A comprehensive literature review was conducted by searching the following databases: PubMed, EMBASE, EBSCO Host, and SCOPUS. Studies published between January 1st, 1975 and March 1st, 2018 were reviewed. The following key words were used in combination with Boolean operators AND or OR for the literature search: "osteonecrosis," "avascular necrosis," "hip," "femoral head," "classification," "reliability," and "validity." We defined the inclusion criteria for qualifying studies for this review as follows: (1) studies that reported on the classification systems for hip osteonecrosis, (2) studies that reported on the inter-observer reliability of the classification systems, and (3) studies that reported on the intra-observer reliability of any ONFH classification systems. In addition, we employed the following exclusion criteria: (1) studies that assessed classification systems for traumatic osteonecrosis, (2) Legg-Calvé-Perthes disease, or (3) developmental dysplasia of the hip. Additionally, we excluded case reports and duplicate studies among searched databases.

Results

Ficat and Arlet

This is the first classification system developed for staging hip osteonecrosis by Ficat and Arlet in 1960s. Despite the fact that it was developed before the advent of magnetic resonance imaging (MRI), it remains the most widely used system nowadays by many orthopaedic surgeons. It is also the most reported system by studies on hip osteonecrosis [12]. It has also been modified multiple times [12]. However, the four-stage version is the most widely adopted (see Table 1). Stage I is defined by normal plain radiographic appearance of the femoral head. At this stage, an increased uptake of tracer on bone scintigraphy or increased bone marrow signal with edema on MRI may exist. Stage II is defined by presence of diffuse sclerosis and cysts representing bone reparation and a pre-collapse stage. Stage III is characterized by subchondral fractures which sometimes can mimic a crescent near the articular cortex; hence, it is known as the "crescent sign" (Fig. 1). Collapse is evident, and flattening may start to occur in this stage (Fig. 2). Stage IV is characterized by further collapse, flattening, and destruction of the femoral head. Secondary osteoarthritic changes start to ensue including joint space narrowing, osteophyte formation, and subchondral bone cysts (Fig. 3). A modification to this system was introduced in 1985 to include stage 0 and a transitional stage.

Table 1 Classification system of Ficat [1]

Stage	Radiographic signs	Clinical features
0	Inconspicuous/normal findings	0 ("silent hip")
I	Inconspicuous findings or minor changes (slight patchy osteoporosis, blurring of trabecular pattern, subtle loss of clarity)	+
II A	Diffuse/ focal radiological changes (osteoporosis, sclerosis, cysts)	+
II B	Subchondral fracture ("crescent sign") segmental flattening of femoral head ("out-of-round appearance")	+
III	Broken contour of femoral head, bone sequestrum, joint space normal	++
IV	Flattened contour of femoral head, decreased joint space collapse of femoral head, acetabular osteoarthritic changes	+++

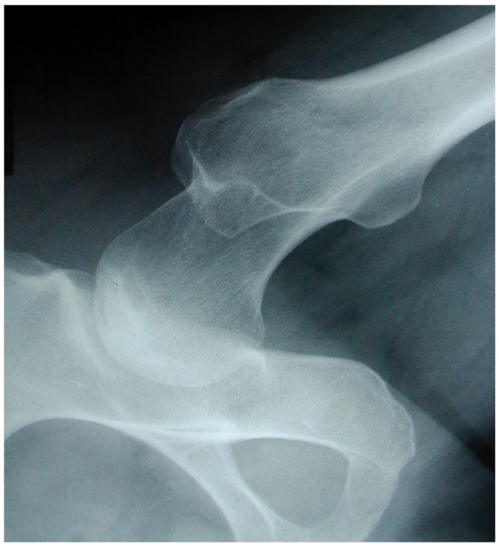

Fig. 1 Plain X-ray of the hip joint showing early degree of femoral head osteonecrosis with diffuse sclerosis and subchondral fracture as demonstrated by the crescent sign. In the Ficat classification, this will correspond to stage IIB

The Ficat and Arlet is a simple and easy to use system. However, it has been criticized for not specifically incorporating MRI findings. In addition, a controversy exits as to whether hips that demonstrate a crescent sign without chondral flattening should be grouped with those that showed gross flatting of the femoral head [14, 15, 19]. In addition, multiple studies questioned the inter- and intra-observer reliability of the classification system. Kay et al. [20] evaluated the adequacy of plain radiographs using the Ficat classification. They found

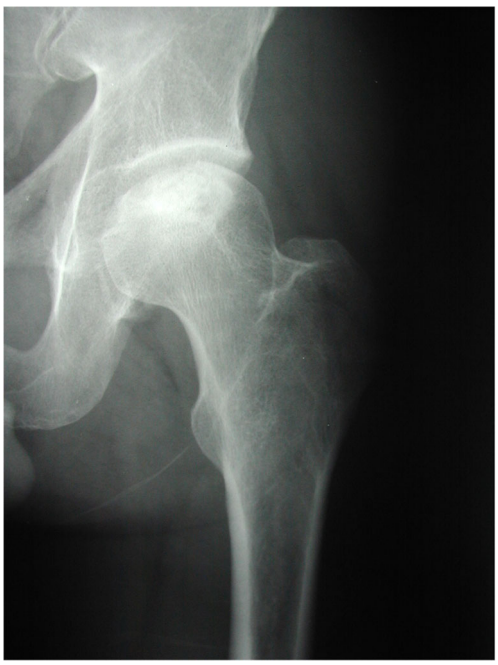

Fig. 2 Plain X-ray showing a more advanced degree of hip osteonecrosis. Broken contour of the femoral head and bone sequestrum is demonstrated (Ficat stage III)

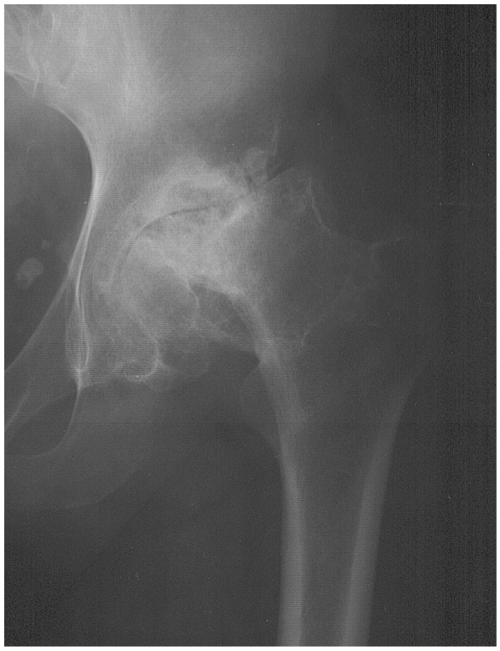

Fig. 3 End-stage joint destruction in femoral head osteonecrosis and secondary osteoarthritic changes

that the inter-observer variability was significantly different in 36% of the hips read, with a low kappa (K) statistic value of 0.56. Intra-observer variability was similar, as 40% of hips had a significant difference, with a kappa statistic (K) of 0.82. They concluded that plain radiographs alone were inadequate to evaluate avascular necrosis (AVN) of the hip. Inter-observer reliability and intra-observer reproducibility of the Ficat classification were also assessed by Schmitt-Sody et al. [21] with plain radiographs and MRI. Their results revealed mean inter-observer kappa reliability coefficients of 0.39 and 0.32 for the first and second reviews, respectively, and means of 0.39 and 0.34 in the first and second reading for the MRI. For intra-observer reproducibility, the mean kappa value was 0.52 for radiographs and 0.50 for MRI. The poor inter-observer reliability and intra-observer variability led them to conclude that Ficat is not sufficient for reliably assessing the status of AVN. Other studies [12, 22] involving the Ficat classification system demonstrated that it had insufficient inter- and intra-observer reliability and could not be used alone to classify and stage hips with ONFH.

Steinberg classification

Steinberg et al. [15] proposed another classification system based on the early Ficat system. In this seven-stage system, the authors used both plain radiographs, bone scans, and MRI images to stage the disease based on lesion size, morphology, and gross changes in the femoral head (see Table 2**).** This more detailed staging system was the first to incorporate the size of the lesion into a classification. Stage 0 is characterized

Table 2 Classification system of Steinberg [15]

Stage	Criteria
0	Normal radiograph, bone scan, and magnetic resonance images
I	Normal radiograph. Abnormal bone scan and/or magnetic resonance images A: Mild (< 15% of femoral head affected) B: Moderate (15 to 30% of femoral head affected) C: Severe (> 30% of femoral head affected)
II	Cystic and sclerotic changes in femoral head A: Mild (< 15% of femoral head affected) B: Moderate (15 to 30% of femoral head affected) C: Severe (> 30% of femoral head affected)
III	Subchondral collapse without flattening (crescent sign) A: Mild (< 15% of articular surface) B: Moderate (15 to 30% of articular surface) C: Severe (> 30% of articular surface)
IV	Flattening of femoral head A: Mild (< 15% of surface and < 2 mm of depression) B: Moderate (15 to 30% of surface and 2 to 4 mm of depression) C: Severe (> 30% of surface and > 4 mm of depression)
V	Joint narrowing or acetabular changes A: Mild B: Moderate C: Severe
VI	Advanced degenerative changes

by absent clinical symptoms and any radiographic changes. Stage I is characterized by normal-appearing plain radiographs, with only MRI or bone scan changes suggestive of early disease. Stage II is characterized by diffuse or localized areas of sclerosis or cystic changes in the femoral head. Stage III is an early collapse stage with crescent sign and no flattening of the femoral head. Stage IV is a separate stage for lesions associated with flattening of the femoral head. Stage V shows acetabular changes in addition to the flattening of the femoral head, but without acetabular involvement. Stage VI is for late cases with advanced secondary degenerative changes involving both sides of the joint.

As in the Ficat classification system, the inter- and intra-observer reliability of the system has been criticized. Plakseychuk et al. [19] determined the inter-observer and intra-observer reliability of the Steinberg classification system of plain radiographs. Their results for the inter-observer variation for each stage of the system showed moderate agreement for stages I and II (stage I, K = 0.64; stage II, K = 0.51), poor agreement for stages III, IV, and V (stage III, K = 0.21; stage IV, K = 0.49; stage V, k = 0.36), and excellent agreement in stage VI (K = 0.80). Their results for intra-observer variation showed excellent agreement for stages I and VI (stage I, k = 0.74; stage VI, k = 0.78), moderate agreement for stages II and IV (stage II, k = 0.60; stage IV, k = 0.59), and poor agreement for stages III and V (stage III, k = 0.46; stage V, k = 0.27). An average of 48% of errors involved stage III, with 30% of intra-observer errors involving stage V. They concluded that the overall reliability of any four- to six-stage classification system was markedly diminished. This is slightly at odds to what Takashima et al. [23] found. They examined the inter- and intra-observer reliability of the system and found that inter-observer reliability was moderate (K = 0.56; range, 0.24–0.84), while the intra-observer reliability was substantial (K = 0.78; range, 0.66–0.90). However, some of the hips assessed had collapses during follow-up that required THA, and their conclusion was that despite having good kappa scores, the Steinberg system was not as reliable as other methods of classification.

Association Research Circulation Osseous

The ARCO system improved on the Ficat and Steinberg models by incorporating radiographs, computed tomography (CT), MRI, and scintigraphy to determine the size and location of necrotic area [16], following a meeting of the ARCO group in 1991. The goal was to establish a unified and comprehensive classification system. However, multiple subsequent modifications and lack of consensus over the final form to be utilized limited the widespread adoption of the system. The system consisted of five stages (stages 0 to 4) and incorporated the location of the lesion as in sub-classification categories. It also maintained size of the lesion as one of the parameters from the Steinberg classification (see Table 3).

Similar to previous systems, multiple studies have attempted to assess and compare the performance of the ARCO classification system in clinical setting. Schmitt-Sody et al. [21] evaluated ARCO in comparison to Ficat and reported a mean inter-observer reliability coefficient of 0.37 in the first reading and 0.31 in the second reading. They also reported a reproducibility of 0.43. Their conclusion was that ARCO was not sufficient for reliably assessing the status of AVN. In addition, Stöve et al. [24] evaluated the ARCO classification, finding it had insufficient inter-observer reliability ($r = 0.51$–0.55), but sufficient intra-observer reliability ($r = 0.73$–0.76). However, they still concluded that ARCO alone was insufficient to reliably assess the status of a hip with osteonecrosis.

The Japanese Investigation Committee classification

The JIC classification, which has been adopted by the Japanese Ministry of Health, Labor and Welfare (JMHLW), utilizes MRI images to classify osteonecrosis based on the location of the necrotic lesion (see Table 4). The basic principle unique to this classification system is that the location of the necrotic lesion relative to the acetabular weight bearing region may be an important factor that determines the final prognosis [25–27]. This is particularly true if in early stages of the disease, lesions are small. Independent of the size, the location of the lesion becomes an important prognostic factor as lesions in a weight-bearing area can quickly progress to

Table 3 Classification system of the Association Research Circulation Osseous [16]

Stage	Findings	Techniques	Subclassification	Quantitation
0	None	Radiography, computed tomography, scintigraphy, magnetic resonance imaging	No	No
1	Radiography and computed tomography normal. At least ONE of the other techniques is positive	Scintigraphy, magnetic resonance imaging	Location of lesion Medial Central Lateral	Area of involvement (percentage) A: Minimal (< 15%) B: Moderate (15 to 30%) C: Extensive Length of crescent A: < 15% B: 15 to 30% C: > 30% Surface collapse and dome depression A: < 15% and < 2 mm B: 15 to 30% and 2 to 4 mm C: > 30% and > 4 mm
2	Sclerosis, osteolysis, focal osteoporosis	Radiography, computed tomography, scintigraphy, and magnetic resonance imaging	Same as stage 1	Same as stage 1
3	CRESCENT SIGN and/or flattening of articular surface	Radiography and computed tomography	Same as stage 1	Same as stage 1
4	Osteoarthritis, acetabular changes, joint destruction	Radiography only	No	No

collapse and conversely, those in non-weight bearing area may not progress to collapse until late [28, 29]. The classification system therefore proposed three stages. In stage A, lesions occupy the medial one-third or less of the weight bearing portion. In stage B, lesions occupy the medial two-thirds or less of the weight-bearing portion. In stage C, lesions occupy more than the medial two-thirds of the weight-bearing portion. This stage has two sub-categories; in stage C1, lesions do not extend laterally, and in stage C2, lesions extend laterally to the acetabular edge.

Unique to the JIC classification system is a reported higher degree of inter- and intra-observer reliability. Takashima et al. [23] compared the JIC classifications to other classification systems while simultaneously examining the inter- and intra-observer reliability. The JIC inter-observer reliability was shown to be substantial (K = 0.72; range, 0.30–0.90), with a higher reliability than both the Steinberg and Kerboul classifications (both $p < 0.001$). The intra-observer reliability was also noticeably high (K = 0.88; range, 0.83–0.97) for JIC. The authors reported that none of the hips designated as JIC type A collapsed or required THA, concluding that the JIC classification was more reliable and effective than other more commonly utilized classification systems including the Steinberg system.

Table 4 Radiographic classification system of the Japanese Investigation Committee [17]

Finding
Lesions occupy the medial one-third or less of the weight bearing portion
Lesions occupy the medial two-thirds or less of the weight-bearing portion
Lesions occupy more than the medial two-thirds of the weight-bearing portion C1—lesions do not extend laterally C2—lesions extend laterally to the acetabular edge

Conclusion

Deciding the best treatment option for a relatively young and more active patient presenting with ONFH can be challenging, particularly when priority is given to the select patient that may benefit from a hip preservation procedure. The journey of the decision-making starts with selecting a good classification system that offers reproducibility and accuracy in judging disease progression, while being clinically relevant to the treatment options. In this review, we aimed to discuss the most commonly utilized systems and update the reader with a current review on the most widely utilized systems. To date, there is a lack of consensus on a universal and comprehensive system, and the use of any of the previous classification systems is a matter of dealer's choice. The Ficat and Arlet system was the earliest yet remains the most widely utilized system. Newer classification systems have been developed and some such as the JIC show promising prognostic value while maintaining simplicity. However, larger validating studies are needed. While all of these systems have their strengths, the lack of a unified classification and staging system is still a

problem in the diagnosis and prognosis of ONFH. Further multi-center collaborative efforts among osteonecrosis experts are needed to adopt a universal classification system that may positively reflect on patient's outcomes.

Compliance with ethical standards

Conflict of interest Assem A. Sultan, MD: nothing to disclose.
Nequesha Mohamed, MD: nothing to disclose.
Linsen T. Samuel, MD, MBA: nothing to disclose.
Morad Chughtai, MD.
Cymedica: Paid consultant.
DJ Orthopedics: Paid consultant.
Peerwell: Paid consultant.
Refelection: Paid consultant.
Sage Products: Paid consultant.
Stryker: Paid consultant.
Nipun Sodhi, BA: nothing to disclose.
Viktor Erik Krebs, MD.
Journal of Arthroplasty: Editorial or governing board.
Stryker: IP royalties; Paid presenter or speaker.
Stryker Orthopedics: Paid consultant.
Kim L Stearns, MD.
Fidiapharma: Paid presenter or speaker.
Robert M. Molloy, MD.
Stryker: Paid consultant; Paid presenter or speaker; Research support.
Zimmer: Research support.
Michael A Mont, MD.
AAOS: Board or committee member.
Abbott: Paid consultant.
Cymedica: Paid consultant.
DJ Orthopedics: Paid consultant; Research support.
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Journal of Arthroplasty: Editorial or governing board.
Journal of Knee Surgery: Editorial or governing board.
Mallinckrodt Pharmaceuticals: Paid consultant.
Microport: IP royalties.
National Institutes of Health (NIAMS & NICHD): Research support.
Ongoing Care Solutions: Paid consultant; Research support.
Orthopedics: Editorial or governing board.
Orthosensor: Paid consultant; Research support.
Pacira: Paid consultant.
Peerwell: Stock or stock Options.
Performance Dynamics Inc.: Paid consultant.
Sage: Paid consultant.
Stryker: IP royalties; Paid consultant; Research support.
Surgical Techniques International: Editorial or governing board.
TissueGene: Paid consultant; Research support.

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