Important Signs in Musculoskeletal MRI

Qian Dong1*, Jon A. Jacobson1, Catherine J. Brandon1, Gandikota Girish1, Yoav Morag1 and Sung Moon Kim1

1Division of Musculoskeletal Radiology, Department of Radiology, University of Michigan Health System, 1500 E. Medical Center Drive, Ann Arbor, MI 48109-5326, USA.

Authors’ contributions

This work was carried out in collaboration between all authors. Study concepts/study design or data analysis/interpretation. Author QD performed the manuscript drafting, manuscript editing. Authors QD, JAJ and CJB performed the manuscript revision for important intellectual content. Authors QD, GG, YM, CJB and SMK performed the literature research. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/BJMMR/2015/14501

Editor(s):
(1) Masahiro Hasegawa, Department of Orthopaedic Surgery, Mie University Graduate School of Medicine, Japan.

Reviewers:
(1) Anonymous, Japan.
(2) Timothy Hui, Loma Linda University, Loma Linda, USA.

Complete Peer review History: http://www.sciencedomain.org/review-history.php?id=721&id=12&aid=7269

Received 1st October 2014
Accepted 20th November 2014
Published 15th December 2014

ABSTRACT

The purpose of this article is to review the common MRI signs of musculoskeletal pathology. In this article, 15 classic MRI signs used in musculoskeletal radiology are presented and described. These signs include the anterior drawer sign, bone bruise sign, bow tie sign, celery stalk anterior cruciate ligament (ACL), cyclops lesion, deep lateral femoral notch sign, double line sign, double Oreo cookie sign, double posterior cruciate ligament (PCL) sign, fat-blood interface (FBI) sign, fragment in notch sign, split fat sign, T-sign, target sign, and yo-yo on a string sign. It is important to recognize common signs in musculoskeletal MRI and understand the underlying pathologies for accurate image interpretation.

Keywords: Magnetic resonance imaging; MRI; musculoskeletal imaging.

*Corresponding author: Email: bingch@umich.edu;
ABBREVIATIONS

MRI, Magnetic resonance imaging; ACL, anterior cruciate ligament; PCL, double posterior cruciate ligament; FBI, fat-blood interface; UCL, ulnar collateral ligament.

1. INTRODUCTION

When the imaging findings of a known disease entity have a consistent pattern or characteristic appearance, those findings may be regarded as an imaging sign. Familiarity with imaging features of these signs helps to shorten the differential list and make the ultimate diagnosis for a patient. As a reliable and accurate modality, magnetic resonance imaging (MRI) has been widely utilized for evaluating many musculoskeletal abnormalities. The objectives of this article are to review several common MRI signs in musculoskeletal imaging, discuss the mechanisms and pathologic factors that produce those findings. Fifteen classic signs used in musculoskeletal MRI are illustrated and discussed, which include the anterior drawer sign, bone bruise sign, bow tie sign, anterior cruciate ligament (ACL), cyclops lesion, deep lateral femoral notch sign, double line sign, double Oreo cookie sign, double posterior cruciate ligament (PCL) sign, fat-blood interface (FBI) sign, fragment in notch sign, split fat sign, T-sign, target sign, and yo-yo on a string sign.

2. ANTERIOR DRAWER SIGN

The primary role of the ACL is to resist anterior subluxation of the tibia. The tibia is subluxed anteriorly when the ligament is torn. Although MRI allows direct visualization of the ACL, it can be challenging sometimes to differential between complete and partial tears [1]. The anterior drawer sign is an important secondary sign seen on sagittal MR images in patients with complete tears of the ACL, which refers to anterior subluxation of the tibia relative to the femur [2]. It is greatest in the lateral compartment of the knee (Fig. 1). The presence of anterior subluxation of the tibia greater than 5 mm relative to the femur on sagittal knee MR images is a helpful adjunctive sign of a complete ACL tear [1]. A subluxation of 7 mm or more has 100% specificity for the presence of a complete ACL tear [2].

Sagittal intermediate-weighted MR image midway through lateral femoral condyle shows 12 mm anterior tibial subluxation. The distance between two parallel vertical lines along posterior margins of lateral femoral and tibial condyles was measured.

3. BONE BRUISE SIGN

The intact ACL normally restrains internal rotation of the tibia. The pivot-shift phenomenon occurs in patients with complete ACL tears. Compressive forces during injury cause impaction of the femoral condyles into the tibial plateau [1]. The bone bruise sign is another valuable secondary sign in acute, complete ACL tears [3]. Subchondral low T1 and high T2 signal abnormality is most commonly seen in both posterolateral tibia and lateral femoral condyle (Fig. 2).

4. BOW TIE SIGN

A sagittal image through either the body of the medial or lateral meniscus produces a bow tie appearance of the low signal meniscus. The body of the normal meniscus averages 9-12 mm in width, thus, "bow ties" should be seen on two 4-5 mm-thick consecutive sagittal images through the body of a normal meniscus [4], called the bow tie sign (Fig. 3). A bucket-handle tear is suggested with absent bow tie, 97% frequency and sensitivity of this absent bow tie sign have been reported [4]. In contrast, three or more contiguous “bow ties” is suggestive of a discoid meniscus [5].

5. CELERY STALK ACL

Celery stalk ACL describes the appearance of ACL with mucoid degeneration [6]. These patients present with mechanical stable ACL and have normal physical examination. Posterior pain has been reported in this group of patients. Theories of pathophysiology, such as prior injury or degeneration of normal tissue, have been reported [7]. MRI findings are specific and should not be mistaken for an ACL tear. Typically, the ACL appears thickened and ill-defined with increased signal intensity on all sequences; however, intact ACL fibers are identified without discontinuity or abnormal orientation (Fig. 4). The appearance mimics a “celery stalk”.

Dong et al.; BJMMR, 6(2): 240-253, 2015; Article no.BJMMR.2015.200
Fig. 1. 28-year-old man with complete ACL tear and anterior drawer sign

Fig. 2. 35-year-old woman with full-thickness ACL tear and bone bruise sign

a, Sagittal STIR and b, intermediate-weighted MR images show bone marrow signal abnormality in both posterolateral tibia and lateral femoral condyle (arrows). Note acute, complete ACL tear (open arrows)
Fig. 3. 56-year-old woman with normal knee and bow tie sign
The bow tie sign (arrows) is revealed in these two adjacent sagittal intermediate-weighted MR images through the body of normal lateral meniscus.

Fig. 4. 65-year-old male with celery stalk ACL and no knee laxity on clinical examination
a, Sagittal intermediate-weighted and b, STIR MR images through intercondylar notch show markedly thickened and ill-defined ACL (arrows) with diffuse increased signal. Note intact ACL fibers.

6. CYCLOPS LESION

The cyclops lesion or localized anterior arthrofibrosis is a focal area of fibrous granulation tissue located anterior to a reconstructed ACL graft, which may require arthroscopic resection. Symptomatic cyclops lesions are reported up to 2% of patients after
ACL reconstruction [8]. Typical clinical presentation of cyclops lesions includes limited full extension. The term “anterior metaplasia” best describes the general tissue source of cyclops lesions [8]. The abnormality appears on MR imaging as a focal soft tissue structure with intermediate signal intensity anterior to the distal aspect of the ACL graft in the intercondylar notch on all sequences [8] (Fig. 5).

7. DEEP LATERAL FEMORAL NOTCH SIGN

An impacted subchondral fracture during ACL injury results in an abnormality at the deep lateral femoral sulcus, which is identified as the deep lateral femoral notch sign [9]. MR imaging shows a deep indentation in the lateral femoral condylopatellar sulcus measuring more than 1.5 - 2 mm in depth [9], usually with associated subchondral bone marrow edema (Fig. 6).

8. DOUBLE LINE SIGN

The double line sign on T2-weighted MR images has been considered as a unique feature of osteonecrosis (avascular necrosis), usually in the late stage of the disease [10]. Typically, MR imaging can demonstrate a high signal intensity line inside the peripheral low signal intensity line with serpentine borders on T2-weighted MR images (Fig. 7). The high signal intensity inner zone represents hyperemic granulation tissue, while the low signal intensity outer zone represents adjacent sclerotic bone [11]. A single low signal intensity band may be seen on a corresponding T1-weighted MR images. This sign is seen in up to 80% of cases [10].

9. DOUBLE OREO COOKIE SIGN

The double Oreo cookie sign or configuration is an indication of type 3 SLAP (superior labral anteroposterior) lesion, which is described as a bucket-handle tear of the superior portion of the labrum with an intact biceps attachment [12]. MR arthrography of the shoulder, one area of increased signal medially represents contrast in a normal variant sublabral sulcus or recess, while the more lateral high signal represents contrast in a labral tear in coronal oblique images [13], producing the double Oreo cookie configuration (Fig. 8).

10. DOUBLE PCL SIGN

A bucket-handle tear is a displaced longitudinal meniscal tear, which more commonly involves the medial meniscus. The resulting meniscal fragment displaces toward the intercondylar notch while still attached at the anterior and

---

**Fig. 5.** 30-year-old man with Cyclops lesions and decreased range of motion after ACL reconstruction

a, Sagittal and b, coronal STIR MR images show abnormal soft tissue with intermediate signal intensity in anterior intercondylar region immediately anterior to ACL reconstruction (circles)
posterior horns, which creates the “handle” [14]. On sagittal MR images through the intercondylar notch, the displaced meniscal fragment appears as a band of low signal anteroinferior to the PCL mimicking a second smaller PCL (Fig. 9). The sign from a torn medial meniscus essentially occurs in the presence of an intact ACL, which serves as a barrier to prevent further lateral displacement of the meniscal fragment [15].

11. FBI SIGN

FBI sign is caused by fat and blood accumulating in a joint, known as lipohemarthrosis [16]. This finding is associated with intracapsular fractures or extensive paraarticular soft tissue trauma, and more common in knee fractures, especially those affecting the tibial plateau, but it has also been described in should elbow and his fractures [17]. On T2-weighted or STIR MR images, three distinct layers can be identified, which is a superior layer of fat, a central layer of serum, and a dependent layer of red blood cells (Fig. 10).

![Image of knee MRI with FBI sign](image)

**Fig. 6.** 24-year-old man with full-thickness ACL tear and deep lateral femoral notch sign  
a, Sagittal intermediate-weighted and b, sagittal STIR MR images through region of lateral condylopatellar sulcus show abnormal deep notch over anterior horn of lateral meniscus (arrowheads) and associated subchondral fracture and bone marrow edema. Joint effusion is present (arrows). c, Corresponding finding is shown on lateral radiograph

![Image of knee MRI with osteonecrosis](image)

**Fig. 7.** 49-year old-male with osteonecrosis and double line sign  
a, Axial T2-weighted image of distal tibia shows double line sign as high-signal line inside low-signal line (arrow). b, Sagittal T1-weighted image of distal femur shows single low-signal-intensity line (arrowheads)
Fig. 8. 30-year-old male with SLAP lesion and double oreo cookie sign
Coronal T1-weighted MR arthrography images with fat saturation show high signal (arrows) medially in a sublabral recess or sulcus, and high signal laterally in a labral tear.

Fig. 9. 36-year-old male with medial meniscus bucket hand tear and double PCL sign
Sagittal intermediate-weighted MR image shows low signal band (arrows) anterior and parallel to the PCL (open arrows), which represents displaced fragment of medial meniscus.
12. FRAGMENT IN NOTCH SIGN

The fragment in notch sign is another well-known sign in the diagnosis of bucket-handle meniscal tears [14,18]. On sagittal images, a low signal intensity meniscal fragment may be seen within the intercondylar notch without appearing as a double PCL (Fig. 11a). The displaced meniscal fragment can also be identified on coronal images within the intercondylar notch (Fig. 11b). Observation of this sign is highly suggestive of a bucket handle tear of meniscus [18].

Fig. 10. 20-year-old female with lipohemarthrosis (FBI sign)

a, Axial and b, STIR MR images show lipohemarthrosis with superior fat layer (white arrows), central serum layer (black arrows), and dependent red blood cells (open arrows). Note bone marrow edema (arrowhead) from transient patellar dislocation. Impaction fractures (not shown) involved medial patella and lateral femoral condyle.

Fig. 11. 36-year-old male with medial meniscus bucket-handle tear and fragment in notch sign

a, Sagittal intermediate-weighted MR image shows low signal displaced meniscal fragment in intercondylar notch (arrows) (open arrow PCL). b, Coronal STIR MR image shows displaced meniscal fragment (arrowhead). Note small size of medial meniscus body.
13. SPLIT FAT SIGN

The split fat sign is a characteristic MR imaging feature commonly seen in benign peripheral nerve sheath tumors and lesions of large nerves [19]. It is best identified on T1-weighted MR images as a rim of fat surrounding a usually fusiform shaped soft tissue mass, which is typically longitudinally oriented along the nerve distribution and continuous with the involved peripheral nerve (Fig. 12).

Fig. 12. 42-year-old woman with radial nerve schwannoma and split fat sign
Coronal T1-weighted MR image shows soft tissue mass isointense to muscle with longitudinal orientation along radial nerve distribution. Note continuity with the radial nerve proximally, and rim of surrounding fat (arrows)
14. T-SIGN

The T-sign at MR arthrography of the elbow indicates an undersurface partial-thickness tear of the distal ulnar collateral ligament (UCL) [20]. The intraarticular contrast material extends medial to the sublime tubercle but does not extend into the soft tissues superficial to the UCL (Fig. 13). This finding with normal contrast extending medial to trochea produces the shape of a “T”.

15. TARGET SIGN

The target sign is nearly pathognomonic for neurofibromas, most commonly in plexiform neurofibromas, appearing hyperintense peripherally and hypointense centrally on T2-weighted MR images (Fig. 14) [20]. This MRI appearance reflects the histological zones in neurofibromas, which consists of fibrous tissue with high collagen content centrally and myxoid tissue with high water content peripherally [19].

Fig. 13. 20-year-old man with partial undersurface UCL tear and “T-sign”
Coronal T1-weighted fat saturation MR arthrographic image shows intra-articular contrast normally extending medial to the trochlea, but abnormally extending medial to the sublime tubercle (arrows) producing a “T” shape.
16. YO-YO ON A STRING SIGN

Injury to or avulsion at the UCL of the first metacarpophalangeal joint is known as “gamekeeper’s thumb”. A Stener lesion is described when the completely torn UCL is displaced proximal or superficial to the adductor aponeurosis [21]. On MR images, the Stener lesion has the appearance of a “yo-yo on a string,” where the “yo-yo” is the proximally displaced UCL, appearing as a round low signal structure, and the “string” is the adjacent adductor aponeurosis (Fig. 15).

Fig. 14. 32-year-old man with ulnar nerve neurofibroma and target sign
Coronal T2-weighted MR image shows neurofibroma (arrow) hypointense central region surrounded by hyperintense zone peripherally
17. CONCLUSION

This mini-review article describes several common MRI signs that are useful to assist the radiologist in establishing the correct diagnosis or differential diagnosis in musculoskeletal imaging. Several signs are well known in the radiology and clinical literature such as those associated with injuries to the ACL: anterior drawer sign, bone bruise sign, and deep lateral femoral notch sign, and those associated with meniscal tears: double PCL sign and fragment in notch sign. “Celery stalk” and “bow tie” signs are verbal “graphic aids” for discussion variations in anatomic structures. Other less common terms highlight key imaging features that can discriminate when surgical intervention is needed as the memorable “yo-yo on a string” sign can when discussing tears of the ulnar collateral ligament of the thumb. More specific and specialized signs such as the target sign for neurofibroma nerve sheath tumors and T sign for partial thickness tear of the ulnar collateral ligament of the elbow. While the radiology literature may propose several new signs from time to time, signs that are descriptive, memorable, and fill diagnostic need such as the ones we have presented in this article are most likely to become part of the day-to-day practice in musculoskeletal MRI.

ETHICAL APPROVAL

Institutional review board approval was obtained before commencing this retrospective study with informed consent waived.

COMPETING INTERESTS

Authors have declared that no competing interests exist.
REFERENCES

1. Chan WP, Peterfy C, Fritz RC, Genant HK. MR diagnosis of complete tears of the anterior cruciate ligament of the knee: Importance of anterior subluxation of the tibia. AJR American journal of roentgenology. 1994;162(2):355-60. PubMed PMID: 8310927.

2. Vahey TN, Hunt JE, Shelbourne KD. Anterior translocation of the tibia at MR imaging: A secondary sign of anterior cruciate ligament tear. Radiology. 1993;187(3):817-9. PubMed PMID: 8497637.

3. Murphy BJ, Smith RL, Uribe JW, Janecki CJ, Hechtman KS, Mangasarian RA. Bone signal abnormalities in the posterolateral tibia and lateral femoral condyle in complete tears of the anterior cruciate ligament: A specific sign? Radiology. 1992;182(1):221-4. PubMed PMID: 1727286.

4. Helms CA, Laorr A, Cannon WD, Jr. The absent bow tie sign in bucket-handle tears of the menisci in the knee. AJR American journal of roentgenology. 1998;170(1):57-61. PubMed PMID: 9423600.

5. Silverman JM, Mink JH, Deutsch AL. Disoid menisci of the knee: MR imaging appearance. Radiology. 1989;173(2):351-4. PubMed PMID: 2798867.

6. McIntyre J, Moelleken S, Tirman P. Mucoid degeneration of the anterior cruciate ligament mistaken for ligamentous tears. Skeletal radiology. 2001;30(6):312-5. PubMed PMID: 11465770.

7. Lintz F, Pujol N, Boisrenoult P, Bargoin K, Beaufils P, Dejour D. Anterior cruciate ligament mucoid degeneration: A review of the literature and management guidelines. Knee surgery, sports traumatology, arthroscopy : Official journal of the ESSKA. 2011;19(8):1326-33. PubMed PMID: 21331652.

8. Bradley DM, Bergman AG, Dillingham MF. MR imaging of cyclops lesions. AJR American journal of roentgenology. 2000;174(3):719-26. PubMed PMID: 10701615.

9. Cobby MJ, Schweitzer ME, Resnick D. The deep lateral femoral notch: An indirect sign of a torn anterior cruciate ligament. Radiology. 1992;184(3):855-8. PubMed PMID: 1509079.

10. Zurlo JV. The double-line sign. Radiology. 1999;212(2):541-2. PubMed PMID: 10429715.

11. Saini A, Saiuddin A. MRI of osteonecrosis. Clinical radiology. 2004;59(12):1079-93. PubMed PMID: 15556590.

12. Mohana-Borges AV, Chung CB, Resnick D. Superior labral anteroposterior tear: Classification and diagnosis on MRI and MR arthrography. AJR American journal of roentgenology. 2003;181(6):1449-62. PubMed PMID: 14627555.

13. Beltran J, Bencardino J, Mellado J, Rosenberg ZS, Irish RD. MR arthrography of the shoulder: Variants and pitfalls. Radiographics : A review publication of the Radiological Society of North America, Inc. 1997;17(6):1403-12. Discussion 12-5. PubMed PMID: 9397454.

14. Weiss KL, Morehouse HT, Levy IM. Sagittal MR images of the knee: A low-signal band parallel to the posterior cruciate ligament caused by a displaced bucket-handle tear. AJR American journal of roentgenology. 1991;156(1):117-9. PubMed PMID: 1898543.

15. Camacho MA. The double posterior cruciate ligament sign. Radiology. 2004;233(2):503-4. PubMed PMID: 15516620.

16. Kier R, McCarthy SM. Lipohemarthrosis of the knee: MR imaging. Journal of computer assisted tomography. 1990;14(3):395-6. PubMed PMID: 2335607.

17. Bhagwat KA, Rajagopal D, Ramesh SD. MR imaging of lipohaemarthrosis in knee joint. J Pub Health Med Res. 2013;1(2):95-6.

18. Ververidis AN, Verettas DA, Kazakos KJ, Tilkeridis CE, Chatzipapas CN. Meniscal bucket handle tears: A retrospective study of arthroscopy and the relation to MRI. Knee surgery, sports traumatology, arthroscopy : Official journal of the ESSKA. 2006;14(4):343-9. PubMed PMID: 16163557.

19. Murphey MD, Smith WS, Smith SE, Kransdorf MJ, Temple HT. From the archives of the AFIP. Imaging of musculoskeletal neurogenic tumors: Radiologic-pathologic correlation. Radiographics: A review publication of the Radiological Society of North America, Inc. 1999;19(5):1253-80. PubMed PMID: 10489179.
20. Ly JQ, Sanders TG, Beall DP. MR imaging of the elbow: A spectrum of common pathologic conditions. Clinical imaging. 2005;29(4):278-82. PubMed PMID: 15967321.

21. Rosner JL, Zlatkin MB, Clifford P, Ouellette EA, Awh MH. Imaging of athletic wrist and hand injuries. Seminars in musculoskeletal radiology. 2004;8(1):57-79. PubMed PMID: 15085478.

© 2015 Dong et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here: http://www.sciencedomain.org/review-history.php?id=721&id=12&aid=7269