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CMEARTICLE

# Clinics in diagnostic imaging (139)

*Wei Yang Lim*[1], MBBS, FRCR, *Nor Azam Mahmud*[2], MD, MMed, *Wilfred CG Peh*[3], FRCP, FRCR

**Fig. 1** Sagittal fat-suppressed PD-W MR image of the right knee taken in the plane of the posterior cruciate ligament.

**Fig. 2** Coronal fat-suppressed PD-W MR image taken at the level of the intercondylar notch.

## CASE PRESENTATION

A 58-year-old Indian man sustained a road traffic accident a few years ago. He presented with sudden onset of pain and swelling on the medial aspect of his right knee. He was unable to weight-bear on his knee and walk. On physical examination, the patient had a right knee effusion, with range of knee movement of 5–120 degrees. There was tenderness of his medial joint line. Radiograph of the right knee was unremarkable. What do the magnetic resonance (MR) images of his right knee (Figs. 1 & 2) show? What is the diagnosis?

[1]Department of Diagnostic Radiology, Tan Tock Seng Hospital, Singapore [2]Department of Diagnostic Radiology, University Science Malaysia, Malaysia, [3]Department of Diagnostic Radiology, Khoo Teck Puat Hospital, Singapore

**Correspondence**: Dr Wei Yang Lim, Registrar, Department of Diagnostic Radiology, Tan Tock Seng Hospital, 11 Jalan Tan Tock Seng, Singapore 308433. drlimweiyang@yahoo.com

## IMAGE INTERPRETATION

MR images of the right knee show a displaced bucket-handle tear of the medial meniscus. The torn fragment (arrows) was displaced into the intercondylar notch (Figs. 1& 2) and was seen as a curvilinear mass anterior to the posterior cruciate ligament (PCL), which gives the double PCL sign on the sagittal image (Fig. 1). Additional complex tears were noted in the posterior horn of the medial meniscus. The medial collateral ligament was slightly thickened with hyperintense signal, in keeping with a Grade 2 medial collateral ligament strain. Moderate joint effusion was also present. The lateral meniscus and the anterior and posterior cruciate ligaments were normal.

## DIAGNOSIS

Displaced medial meniscus bucket-handle tear.

## CLINICAL COURSE

Two weeks after the MR imaging, the patient underwent surgery. During the operation, a chronic bucket-handle tear of the medial meniscus was seen. This was considered to be non-repairable. Otherwise, the lateral meniscus, anterior cruciate and posterior cruciate ligaments were intact. Debridement of the medial meniscus was performed. The patient subsequently underwent a course of physiotherapy. On follow-up in the orthopaedic clinic, he could extend his knee fully.

## DISCUSSION

The menisci are semi-lunar (C-shaped) fibrocartilage structures comprising predominantly type 1 collagen arranged primarily in a circumferential fashion, which gives the menisci the tensile strength.[1] Each meniscus has a concave superior surface and a flat inferior surface. These properties allow the menisci to serve a multitude of functions, such as distribution of stresses over the articular cartilage, shock absorption, stabilisation of the knee in flexion and extension, joint lubrication and secondary stabilisation of the knee after anterior cruciate ligament (ACL) injury.[1,2] The meniscus consists of a central avascular zone and a peripheral vascularised area, also known as the red zone.[1-3] Its vascularity is important in the repair and healing of the meniscus. Each meniscus is divided arbitrarily into an anterior horn, body and a posterior horn. The anterior and posterior horns of both menisci attach to the anterior and posterior tibial plateau, respectively, at their root attachments. Closely-related ligaments include the anterior intermeniscal ligaments, meniscofemoral ligaments of Humphrey or Wrisberg and popliteomeniscal fascicles.[1,2] On MR imaging, the menisci, being highly organised collagen structures, are homogeneously hypointense on all sequences.[1,2] Normal anterior and posterior horns of the menisci have a triangular appearance on the sagittal MR images and should not measure more than 6 mm in height.[4] The medial meniscus is typically larger than the lateral meniscus and has a wider posterior horn.[1]

The standard validated traditional MR pulse sequence is the proton density (PD)-weighted spin-echo sequence, with a long repetition time and short echo time.[2,5] Fast spin-echo PD-weighted sequences reduce the imaging time but may have a slightly lower sensitivity in detecting meniscal tears compared to conventional spin-echo sequences.[5] Fat suppression can also be performed to increase the dynamic range of the signal in the menisci, making tears more conspicuous, and to distinguish fat from fluid on fast spin-echo sequences.[5] Current imaging techniques employ an extremity coil, with slice thickness of 3–4 mm, inter-slice gap of 0–0.5 mm, a field-of-view ≤ 16 cm and matrix size of at least 256 × 192.[1]

Meniscal tears can be caused by either increased force on a normal meniscus, usually resulting in longitudinal or radial tears, or normal forces on a degenerative meniscus, usually producing horizontal tears in the posterior half of the meniscus.[1] The diagnostic criteria of meniscal tears on MR imaging consist of an abnormal signal within the meniscus that extends to the meniscal articular surface and abnormal meniscal morphology. Meniscal tears can be described as vertical, horizontal or complex.[1] Meniscal lesions are usually best evaluated on both sagittal and coronal images.[6]

The bucket-handle tear is a variant of the vertical tear, and consists of a vertical or oblique tear involving the posterior horn of the meniscus that extends longitudinally through the body and anterior horn. The inner meniscal fragment is often displaced into the intercondylar notch, which resembles a handle, while the larger peripheral portion resembles a bucket.[7] Bucket-handle tears are more commonly seen in the medial meniscus.[1] The tears usually involve younger patients and are associated with a higher incidence of concomitant ACL tears.[8] Several MR imaging signs of a displaced bucket-handle tear have been described, including the double PCL sign, displaced fragment in intercondylar notch sign, absent bow tie sign, anterior flipped meniscus sign and coronal truncation sign.[9] The overall sensitivity of MR imaging for the detection of meniscal bucket-handle tears is 64%–94%.[1,10]

The double PCL sign (Figs. 3a & b) describes the displaced bucket-handle fragment as a linear hypointense band, which is usually parallel to the anterior inferior aspect of the PCL, in the same plane in the midline sagittal MR image. This sign has been reported only in medial meniscus bucket-handle tears and is associated with decreased size of the posterior horn and body of the medial meniscus.[11] Wright et al proposed that the sign is not seen in lateral meniscus bucket-handle tears because the more laterally-located ACL acts as a barrier to the meniscal fragments.[4] The double PCL sign has a low sensitivity of 27%–44% and a high specificity of 98%–100%.[1,9,12,13]

The displaced fragment in the notch sign occurs when a meniscal fragment is seen in the intercondylar notch but not in the same plane as the PCL.[11] This sign is encountered more often in the lateral bucket-handle tears and has a sensitivity of 60%–98% and a specificity of 73%–82%.[1] Rarely, when both medial and lateral bucket-handle tears are present with displacement of the fragments into the intercondylar notch, the displaced fragments, the ACL and PCL result in the appearance of four structures within the intercondylar notch on coronal MR images, hence the name,


**Fig. 3** a) Double-PCL sign in a 27-year-old man with a displaced bucket-handle tear of the medial meniscus. Midline sagittal fat-suppressed PD-W MR image shows the double PCL sign. The displaced meniscal fragment (arrowheads) is located anterior and inferior to the 'real' PCL (arrows). (b) Coronal fat-suppressed PD-W MR image shows the torn fragment (arrowhead) located in the intercondylar notch adjacent to the PCL (arrows). The torn bucket-handle fragment remains attached to the remnant posterior horn of the medial meniscus.

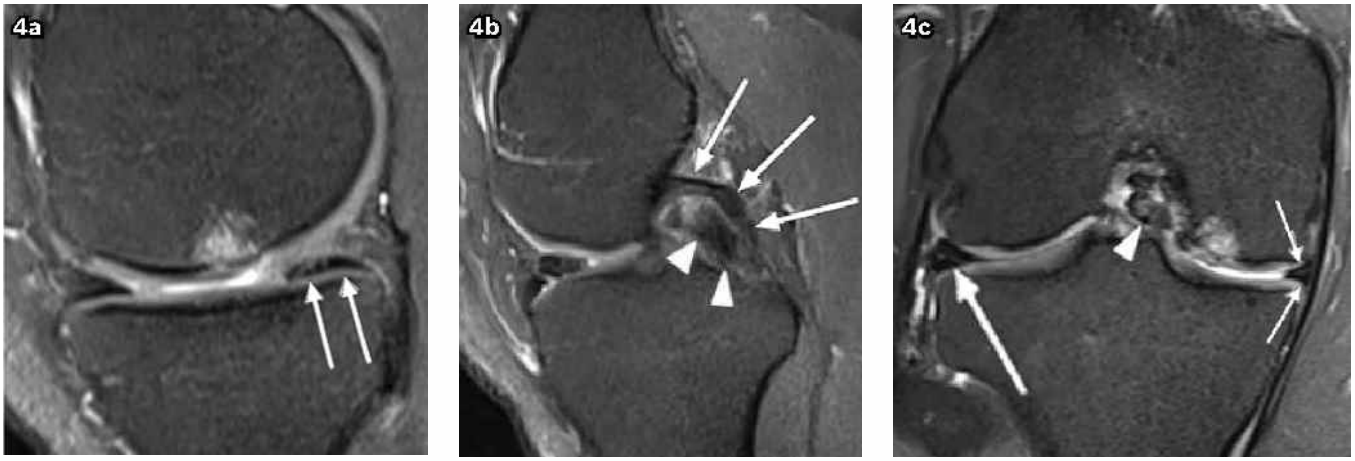


**Fig. 4** Absent bow-tie sign in a 20-year-old man with a displaced bucket-handle tear of the medial meniscus. (a) Peripheral sagittal fat-suppressed PD-W MR image shows the absent bow-tie sign. The remnant posterior horn (arrows) of the medial meniscus is deficient in size and has an abnormal, flattened shape. (b) Midline sagittal fat-suppressed PD-W MR image taken at the level of the intercondylar notch shows a displaced bucket-handle fragment (arrowheads) located anterior to the PCL (arrows). (c) Coronal fat-suppressed PD-W MR image taken at the level of the intercondylar notch shows the displaced bucket-handle fragment (arrowhead). Note that the posterior horn of the remnant medial meniscus is deformed and smaller in size (small arrows) compared to the contralateral meniscus (large arrow). Subchondral bone marrow oedema is seen in the medial femoral condyle in Figs. 4a & c.

'quadruple cruciate sign'.[14] The body of the meniscus is continuous with the anterior and posterior horns on peripheral sagittal MR images, giving rise to a normal bow-tie configuration. The bow-tie sign is considered to be normal when two sagittal images demonstrate the normal bow-tie configuration, and absent when there is only one or none of the body segments detected.[9] The remaining anterior and posterior horns are often hypoplastic or truncated, with or without increased signal intensity.[8,9] The absent bow-tie sign (Figs. 4a & b) has a sensitivity of 58%–98%, although the specificity is 62%–100%.[1,9,15]

The anterior flipped meniscus sign (Figs. 5a & b) describes a bucket-handle tear where there is displacement of the meniscal fragment into the anterior compartment, with the displaced fragment vertically juxtaposed to the ipsilateral anterior horn.[11] This results in an abnormally large anterior horn with a height ≥ 6 mm and a meniscus-shaped hypointense area located just anterior to the normal-shaped anterior horn.[4] The normal anterior horn and the displaced fragment are often indistinguishable.[11] This sign is more commonly seen in medial meniscus bucket-handle tears,[1] with a specificity of 87%, which rises to 96% when utilised in conjunction with the absent bow-tie sign.[15] Occasionally, a variation may occur where the displaced meniscal fragment and ipsilateral anterior horn are not vertically juxtaposed but located next to each other in the same horizontal plane, giving rise to the appearance of two anterior horns, and hence, the 'double anterior horn sign'. The horn that is located more anteriorly represents the normal anterior horn, while the more posterior horn represents the displaced bucket-handle fragment.[11]

The coronal truncation sign (Figs. 6a-c) describes an amputated or deformed meniscus with a deficient meniscal body on coronal

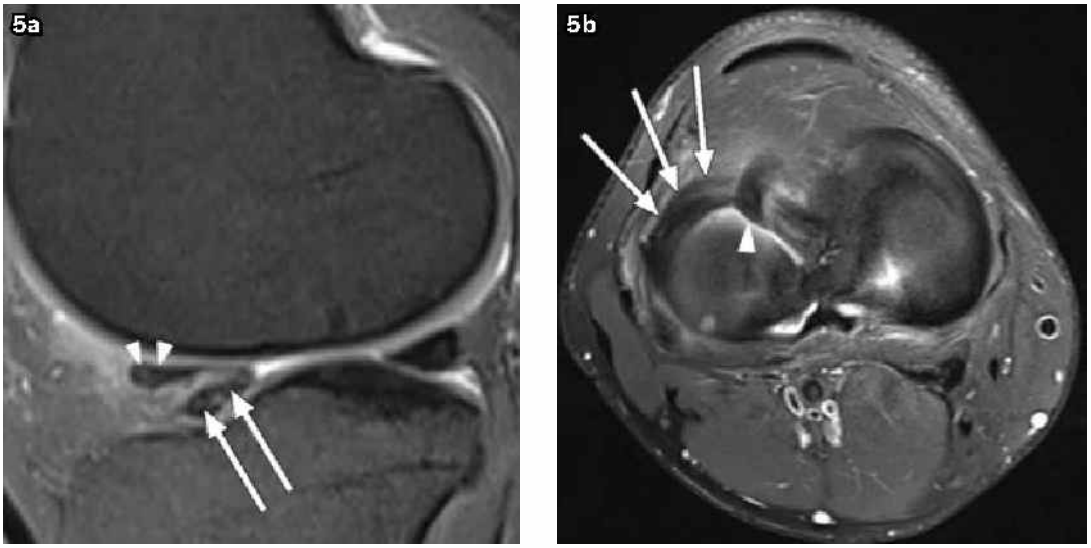


**Fig. 5** Anterior flipped meniscus sign in 27-year-old man with a displaced bucket-handle tear involving the body of the lateral meniscus. (a) Sagittal fat-suppressed PD-W MR image shows the anterior flipped meniscus sign. The displaced fragment (arrowheads) is located adjacent to the normal anterior horn of the lateral meniscus (arrows). This resembles an abnormally large meniscus with abnormal hyperintense linear signal. (b) Axial fat-suppressed PD-W MR image shows a large curvilinear displaced fragment (arrowhead) located adjacent to the normal anterior horn of the lateral meniscus (arrows).

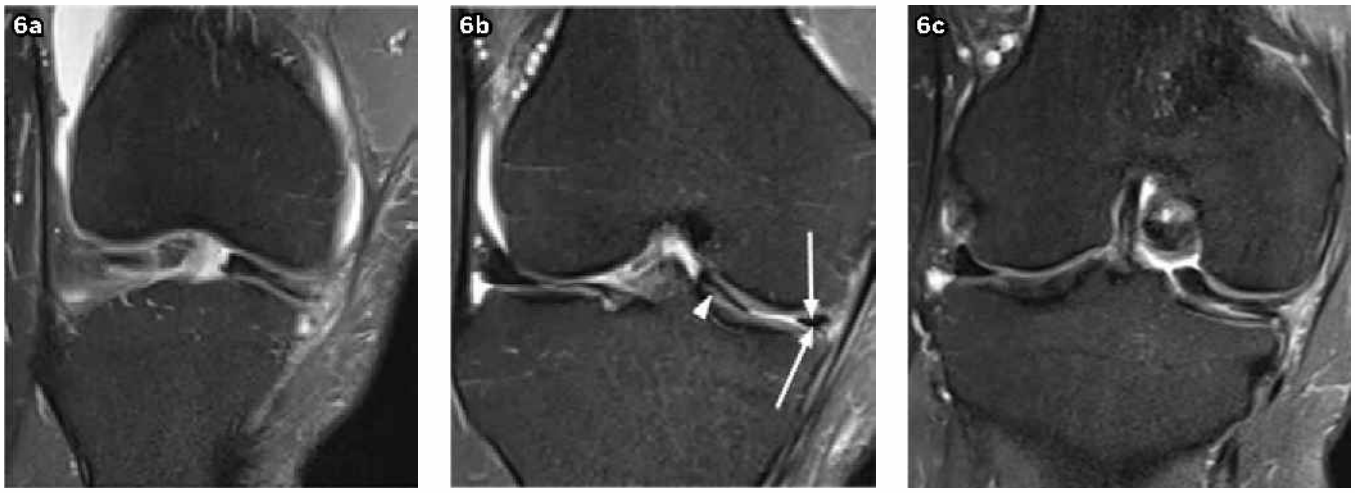


**Fig. 6** Coronal truncation sign in a 30-year-old man with a displaced bucket-handle tear affecting the medial meniscus. (a-c) Coronal fat-suppressed PD-W MR images of the medial meniscus were taken at intervals from (a) anterior to (c) posterior. On the (a) anterior and (c) posterior coronal images, the remnant anterior and posterior horns of the medial mensicus are seen as hypointense bands. (b) On the mid-coronal image, the inner fragment of the medial meniscus (arrowhead) is displaced towards the intercondylar notch (arrowhead). The coronal truncation sign (arrows) of the small deformed remnant of the medial meniscus body is noted. As the components of the torn meniscus are continuous, the meniscus forms complete ring when viewed on the anterior to posterior coronal images.

MR images.[15] This sign is not useful when utilised alone, and has a sensitivity of 65% and specificity of 71% in detecting bucket-handle tears.[15] When the coronal truncation sign is present in combination with the absent bow-tie and displaced fragment signs, the specificity of detected tears is increased to 94%. Utilising a combination of the different MR imaging signs of bucket-handle tears has been shown to increase specificity.[15]

Potential mimics of the double PCL sign include anatomical structures in the intercondylar region, which include intermeniscal ligaments, as well as meniscofemoral ligaments of Humphrey and Wrisberg. Careful examination of the given structure on sequential images can help avoid these pitfalls.[2,13] Abnormal structures such as loose bodies, osteophytes and fracture fragments in the intercondylar region can also be potential mimics.[13] False positives in an absent bow-tie sign can occur in children or small adults and degenerative menisci. Postsurgical changes such as partial meniscectomy can also present with an absent bow-tie sign; however, this pitfall can be easily avoided by obtaining a proper history.[5,15] A radial tear can present with an absent bow-tie sign, and this can be differentiated from a bucket-handle tear by careful examination and the absence of a displaced fragment.[15]

The surgical treatment options of bucket-handle meniscal tears include partial and complete meniscectomy and meniscal repair. The choice of treatment depends on the location and size of the tear. Meniscal repair aims to restore normal biomechanical function, while partial meniscectomy removes unstable tissues while preserving as much meniscus as possible, especially the outer vascular red zone.[1] Clinical success rates of meniscal repair

have been shown to be poorer in patients with bucket-handle tears compared to those with simple tears.[16] Shelbourne and Carr found no difference in the outcomes of patients with bucket-handle tears and ACL tears who have undergone either meniscal repair or partial meniscectomy.[17]

## CONCLUSION

MR imaging is accurate in diagnosing bucket-handle tears of the meniscus, with detection of the displaced fragment in the intercondylar notch and the absent bow-tie signs being the most sensitive signs, and double PCL sign being the most specific for a medial meniscus bucket-handle tear. Specificity is increased when a combination of the different MR imaging signs is present. It is important to understand the meniscal anatomy and the potential mimics of bucket-handle tears in order to ensure an accurate diagnosis.

**ABSTRACT** A 58-year-old man presented with knee pain and swelling, following a previous injury. A displaced bucket-handle tear of the medial meniscus was diagnosed on magnetic resonance (MR) imaging and subsequently confirmed by arthroscopy. MR imaging is accurate in diagnosing bucket-handle tears. The different MR imaging signs of bucket-handle tears include the double posterior cruciate ligament sign, displaced fragment in intercondylar notch sign, absent bow-tie sign, anterior flipped meniscus sign and coronal truncation sign. Specificity is increased when a combination of the different imaging signs is present. Understanding the meniscal anatomy and potential mimics of the bucket-handle tear is important in order to ensure an accurate diagnosis and appropriate management.

*Keywords: bucket-handle tears, displaced meniscal tears, knee injury, meniscal tear, meniscus*
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# SINGAPORE MEDICAL COUNCIL CATEGORY 3B CME PROGRAMME

*(Code SMJ 201204B)*

| | True | False |
|---|---|---|
| **Question 1.** Regarding normal meniscal anatomy: | | |
| (a) The menisci comprise predominantly type 1 collagen. | ☐ | ☐ |
| (b) The meniscus has a central vascularised area and peripheral avascular zone. | ☐ | ☐ |
| (c) The menisci typically show homogeneous hyperintense signal on all sequences. | ☐ | ☐ |
| (d) The medial meniscus is typically larger than the lateral meniscus. | ☐ | ☐ |
| **Question 2.** With regard to meniscal tears: | | |
| (a) Abnormal signal within the meniscus without extension to the articular surface is a diagnostic criterion for a meniscal tear. | ☐ | ☐ |
| (b) Axial MR images are best for evaluation of meniscal lesions. | ☐ | ☐ |
| (c) Bucket-handle tears are more commonly seen in the medial meniscus. | ☐ | ☐ |
| (d) Bucket-handle tears are associated with a higher incidence of concomitant anterior cruciate ligament (ACL) tears | ☐ | ☐ |
| **Question 3.** Regarding MR imaging features in bucket-handle tears: | | |
| (a) The overall sensitivity of MR imaging for the detection of meniscal bucket-handle tears is 10%–30%. | ☐ | ☐ |
| (b) The double posterior cruciate ligament (PCL) sign has been reported only in lateral meniscus bucket-handle tears. | ☐ | ☐ |
| (c) The presence of both medial and lateral bucket-handle tears with displacement of the fragments into the intercondylar notch can result in a quadrate cruciate sign. | ☐ | ☐ |
| (d) An abnormally small anterior horn is seen in the anterior flipped meniscus sign. | ☐ | ☐ |
| **Question 4.** Regarding pitfalls in the diagnosis of bucket-handle tears: | | |
| (a) Intermeniscal ligaments and meniscofemoral ligaments of Humphrey are potential mimics of a double PCL sign. | ☐ | ☐ |
| (b) Patients with degenerative menisci can result in a false positive absent bow-tie sign. | ☐ | ☐ |
| (c) Loose bodies in the intercondylar region can be a potential mimic. | ☐ | ☐ |
| (d) The absence of a displaced fragment is useful to differentiate a radial tear from a bucket-handle tear in an absent bow-tie sign. | ☐ | ☐ |
| **Question 5.** Regarding surgical treatment options of bucket-handle tears: | | |
| (a) Partial and complete meniscectomy are surgical options. | ☐ | ☐ |
| (b) The location and the size of the tear do not affect the choice of treatment. | ☐ | ☐ |
| (c) Partial meniscectomy aims to preserve as much meniscus as possible from the outer vascular zone. | ☐ | ☐ |
| (d) Meniscal repair in simple tears have a poorer clinical success rate compared to bucket-handle tears. | ☐ | ☐ |

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(1) Answers will be published in the SMJ June 2012 issue. (2) The MCR numbers of successful candidates will be posted online at www.sma.org.sg/cme/smj by 21 May 2012. (3) All online submissions will receive an automatic email acknowledgment. (4) Passing mark is 60%. No mark will be deducted for incorrect answers. (5) The SMJ editorial office will submit the list of successful candidates to the Singapore Medical Council. (6) One CME point is awarded for successful candidates.

**Deadline for submission: (April 2012 SMJ 3B CME programme): 12 noon, 14 May 2012.**