

Two Helpful MRI Signs for Evaluation of Posterolateral Bundle Tears of the Anterior Cruciate Ligament

A Pilot Study

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Background: Diagnosis of partial anterior cruciate ligament (ACL) tears is difficult on magnetic resonance imaging (MRI), particularly the isolated tears of the posterolateral bundle.

Purpose: To describe 2 MRI signs of partial ACL tear involving the posterolateral bundle on conventional knee MRI sequences, specifically, the “gap” and “footprint” signs.

Study Design: Case-control study.

Methods: We retrospectively reviewed the MRI appearance of the ACL in 11 patients with arthroscopically proven partial ACL tears isolated to the posterolateral bundle, as well as in 10 patients with arthroscopically proven intact ACLs, and evaluated for the presence of gap and/or footprint signs.

Results: There was high degree of sensitivity and specificity associated with the MRI findings of “gap” and “footprint” signs with arthroscopically proven isolated posterolateral bundle tears.

Conclusion: Gap and footprint signs are suggestive of posterolateral bundle tear of the ACL, and the presence of 1 or both of these imaging findings should alert the radiologist to the possibility of a posterolateral bundle tear.

Keywords: anterior cruciate ligament; posterolateral bundle; tear

Although some magnetic resonance imaging (MRI) signs and manifestations have been proposed to be helpful in diagnoses of partial anterior cruciate ligament (ACL) tears, the diagnosis of a partial ACL tear has been considered difficult using MRI. Isolated ruptures of the anteromedial (AM) or posterolateral (PL) bundle are potentially difficult to diagnose during arthroscopy as well as with physical examination. This presents a challenge to the orthopaedic surgeon, as many surgeons now utilize a different type of reconstruction in the repair of AM bundle versus PL bundle

versus full-thickness ACL tears. To our knowledge, there have been no MRI findings reported specific for isolated tears of the PL bundle of the ACL. In this article, we report 2 imaging signs useful in identified PL tears seen on conventional coronal and axial MRIs of the knee: the “gap” sign and the “footprint” sign.

METHODS

After obtaining institutional review board approval, MRIs of 11 patients with arthroscopically proven tears of the PL bundle of the ACL were retrospectively reviewed by 4 total readers: 2 experienced radiologists (A.K.B. and P.H.P.), 1 senior resident radiologist (Y.V.V.), and 1 experienced orthopaedic surgeon (H.M.S.). Cases were presented to the readers randomly mixed with the MR examinations of 10 patients who had also undergone arthroscopy and were found to have intact PL bundles, and the readers were blinded to both the prior imaging interpretation and surgical results. Because some patients were referred with outside MR examinations, the MR protocols and magnet strengths were variable. Four patients were scanned on

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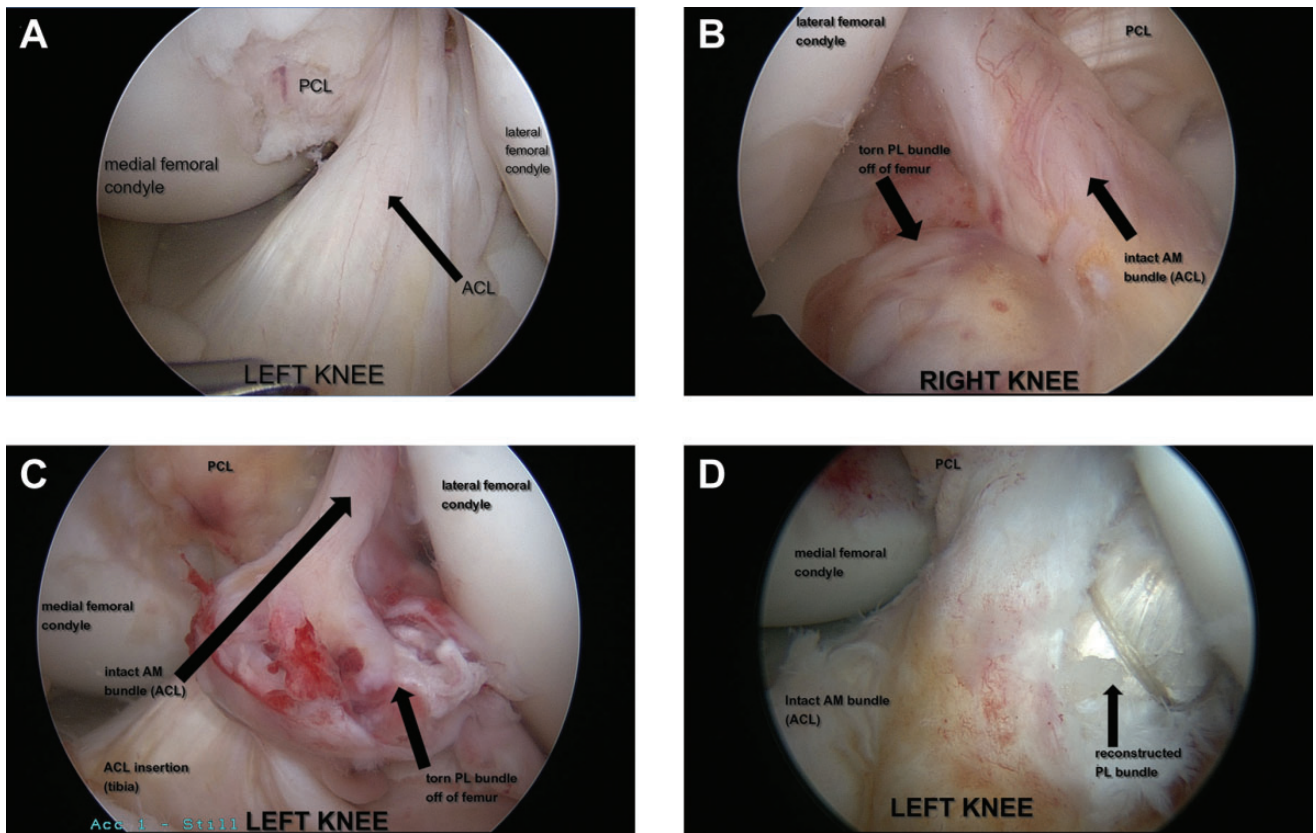


Figure 1. (A) Arthroscopic image demonstrating a normal, intact posterolateral (PL) bundle. (B, C) Arthroscopic images from 2 patients demonstrating torn PL bundles of the anterior cruciate ligament (ACL). (D) Arthroscopic image demonstrates isolated PL bundle reconstruction.

1.5-T units, 4 on 3-T units, and there were 3 patients with outside imaging on magnets of unknown strength. All imaging studies utilized axial, sagittal, and coronal intermediate-weighted fat saturation (IW FS) or proton density fat saturation (PD FS) sequences as well as a coronal intermediate-weighted (IW) or proton density (PD) without fat saturation sequence. Other sequences were included in some of the protocols, but only the coronal, axial, and sagittal IW or PD FS sequences were provided for interpretation.

All arthroscopic procedures were performed at our institution. Standard parapatellar portals were used for diagnostic arthroscopy and an accessory medial portal for PL bundle reconstruction. The PL bundle was identified at the time of arthroscopy with both direct visualization and probing (Figure 1).

Coronal and axial images were evaluated for the presence of 2 signs. The “gap” sign refers to the presence of high signal on IW FS or PD FS images between the medial aspect of the lateral femoral condyle and the lateral aspect of the mid-ACL. This may be visible in either the coronal (Figure 2, A and B) or axial (Figure 3A) planes. In patients with an intact ACL, the ACL hugs the lateral wall of the femoral notch (Figures 2C and 3B). The “footprint” sign refers to incomplete coverage of the lateral aspect of the

interspinous area of the tibia by the distal ACL attachment (Figure 4, A and B). In patients with an intact ACL, the tibial attachment of the ACL spans the distance between the tibial spines (Figure 4C). This is visible in only the coronal plane. The defects resulting in the presence of the gap or the footprint are subtle findings. We did not utilize any specific size criteria in the identification of either sign.

RESULTS

In our series of 11 patients with arthroscopically proven PL bundle tears, the sensitivity of the footprint sign in the coronal plane was 75% and the specificity was 80%. The sensitivity of the gap sign was 72% with a specificity of 68% in the coronal plane. In the axial plane, the sensitivity of the gap sign was 52% and the specificity was 53%. As discussed, the axial images were not evaluated for the footprint sign as it is not visible in this plane. The presence of 1 or both signs had a sensitivity of 82% and a specificity of 58% for the diagnosis of PL bundle tear in this small cohort. Of note, when only the responses of the 3 most experienced readers were evaluated, the sensitivity of each finding decreased, although the specificity increased (Table 1).



Figure 2. (A) Coronal intermediate-weighted fat saturation (IW FS) magnetic resonance image (MRI) of the right knee in a 39-year-old male with arthroscopically proven posterolateral (PL) bundle tear demonstrates the “gap” sign, referring to the gap between the medial aspect of the lateral femoral condyle and the lateral aspect of the proximal anterior cruciate ligament (ACL) attachment. (B) A similar finding is seen in a left knee MRI of a 17-year-old male with arthroscopically proven PL bundle tear (image flipped for easier comparison with the others). (C) For comparison, coronal IW FS MRI in a 12-year-old female demonstrates normal appearance of the PL bundle with no “gap” sign.

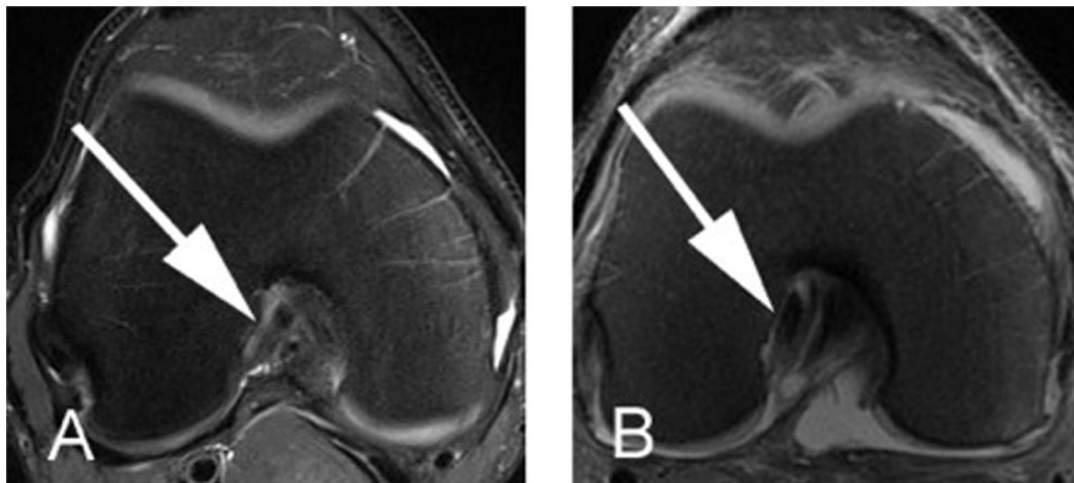


Figure 3. (A) Axial intermediate-weighted fat saturation (IW FS) magnetic resonance image (MRI) of the right knee in a 17-year-old male with arthroscopically proven posterolateral (PL) bundle tear demonstrates the “gap” sign. (B) For comparison, coronal IW FS MRI in a 41-year-old male demonstrates normal appearance of the PL bundle with no “gap” sign.

DISCUSSION

Isolated ruptures of the AM or PL bundle may be difficult to diagnose during arthroscopy as well as with physical examination.⁷ This presents a challenge to the orthopaedic surgeon, as isolated AM or PL bundle reconstruction is becoming a more common treatment for patients with a single-bundle rupture.⁷ The combined findings of the MRI findings, activity level of the patient, as well as arthroscopic examination allow the surgeon to decide between non-operative treatment, ACL augmentation, or standard ACL reconstruction.⁴ MRI study can therefore be a critical element in surgical planning.

The defects in the ACL that produce the gap and footprint signs correlate with the course of the PL bundle, and

it is logical that the absence of fibers in these locations indicates absence of the PL bundle. Our study has demonstrated that if either or both signs are present, the sensitivity for PL bundle tear is high (80%). The footprint sign by itself was found to be both moderately sensitive (75%) and specific (80%) in our small cohort. Identification of the gap sign in the axial plane was found to not be useful, with both a low sensitivity and a low specificity; however, in the coronal plane, both the sensitivity and specificity increased. The detection of these 2 signs does not require special non-orthogonal sequences, and they are readily seen on routinely performed coronal images. This is particularly useful for patients who obtain MRI prior to being examined by an orthopaedic surgeon, when there is often not yet a specific clinical concern for ACL injury, or for those who obtain

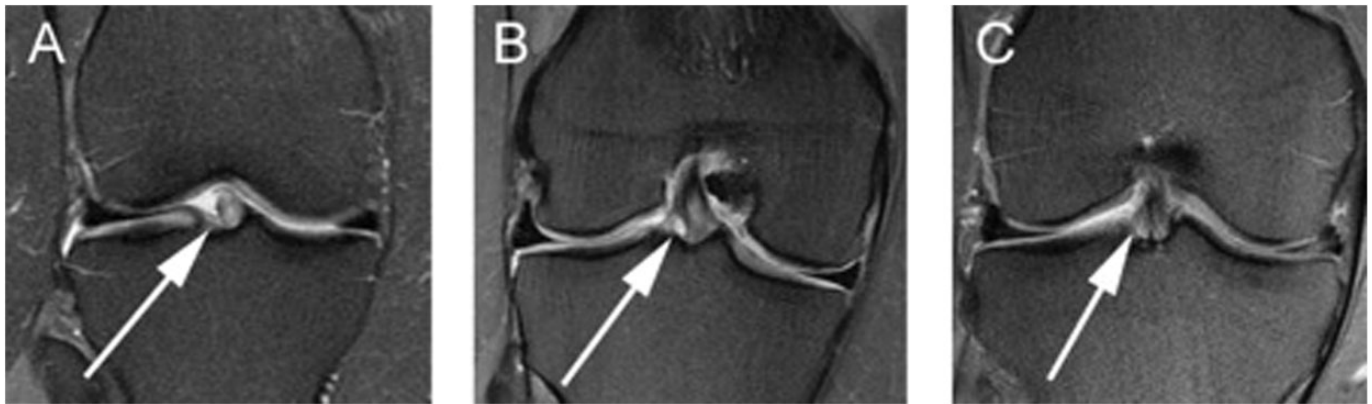


Figure 4. (A) Coronal intermediate-weighted fat saturation (IW FS) magnetic resonance image (MRI) of the right knee in a 38-year-old female with arthroscopically proven posterolateral (PL) bundle tear demonstrates the “footprint” sign, referring to the incomplete coverage of the lateral aspect of the interspinous area of the tibia by the distal anterior cruciate ligament (ACL). (B). Similar finding is seen in a 27-year-old male with arthroscopically proven PL bundle tear. (C) For comparison, coronal IW FS MRI in a 26-year-old male demonstrates normal appearance of the PL bundle of the ACL, with no “footprint” sign.

TABLE 1
Sensitivity and Specificity of the Footprint and Gap Signs

	Mean Interpreted Positive (11 Actual)	Mean Interpreted Negative (10 Actual)	Sensitivity	Specificity	Sensitivity (Experienced Readers)	Specificity (Experienced Readers)
Footprint sign	8.25	8	75	80	70	97
Gap sign, axial	5.75	5.25	52	53	45	53
Gap sign, coronal	8	6.75	72	68	64	83
Both signs	6.25	8.25	57	83	45	97
Either sign	9	5.75	82	58	79	73

their imaging at an outside facility due to insurance or convenience reasons.

With conventional MRI, isolated PL ruptures have traditionally been difficult to diagnose because of the oblique course of this bundle.⁷ An early study by Umans et al¹⁰ found that MRI is not sensitive enough to accurately diagnose partial ACL tears, with the sensitivity of MRI in their study reported to be 0.4 to 0.75 and the specificity 0.62 to 0.89. Lawrance et al⁶ found that, compared with arthroscopy, MRI diagnosed only 1 of 9 partial ACL tears. Neither of these studies differentiated the 2 bundles of the ACL. A later study by Chang et al² did address the 2 separate bundles of the ACL and demonstrated the overall diagnostic accuracy of MRI for detection of partial ACL tears to be 83%, with better accuracy for the AM bundle tears than the PL bundle (91% vs 78%), and more difficult detection of PL bundle tears early after injury when severity of the PL bundle injury is overestimated. However, these investigators did not describe any particular imaging findings or sequences used to identify the PL versus the AM bundle.

Some investigators have attempted to determine ways to increase the diagnostic accuracy of conventional imaging, either by defining MRI criteria for partial ACL ruptures or by optimizing the MRI sequences. Umans et al,¹⁰

Lawrance et al,⁶ and Chen et al³ identified findings helpful in differentiating partial from complete ACL tears; however, as mentioned, they did not differentiate the AM or PL bundles. Van Dyck et al¹¹ also identified signs helpful in differentiating partial from complete ACL tears, but were able to diagnose single-bundle tears in only 6% of their patients and concluded that isolated single-bundle tears could not be identified.

Roychowdhury et al⁸ determined the usefulness of axial MRI for diagnosing partial ACL tears. Using axial MRI, the authors were able to segregate stable ACLs (normal ligaments and stable partial tears) from unstable ACLs (unstable partial tears and complete tears) with 100% sensitivity and 96% specificity. However, they also did not address which of the bundles was involved.

Because of the unique diagonal course of the ACL of the knee, various nonorthogonal MRI techniques have been investigated to determine which offers optimal visualization of the ACL.⁵ Hong et al⁵ demonstrated that additional use of oblique coronal MRI to the standard knee MRI and a 4-point grading scale for ACL injuries were found to significantly increase diagnostic accuracy. Similarly, Araujo et al¹ demonstrated that the oblique coronal sequence increases the sensitivity and specificity of diagnosing isolated AM or PL bundle injuries and also helps visualize the

proximal insertion of the bundles. These authors also used special oblique sagittal plane sequences, running parallel to the ACL, to optimally visualize both the AM and PL bundles. Steckel et al⁹ were able to distinguish the double-bundle AM and PL structures in the cadaveric knees. All these authors utilized specialized sequences for evaluation of the AM and PL bundles, and therefore, their findings are difficult to generalize to standard MR studies that often do not include these sequences.

Our study has little statistical power due to our small cohort, but in this small group of patients, we have identified a significant correlation between the gap and the footprint signs in the coronal plane with the arthroscopic diagnoses of isolated PL bundle tear without requirement for specialized sequences. This is a pilot study, and we did not take into account the age of the injury or the strength of the magnet. We also did not evaluate for the presence of these findings in patients with isolated AM bundle tears. In addition, we did not utilize size criteria in identification of the gap or footprint defects, and it is possible that in doing so we could increase our specificity. A prospective study with a larger cohort should be considered for further validation of our results.

CONCLUSION

The presence of either the gap or footprint signs on coronal MRI, and particularly, the presence of both signs together, are suggestive of the presence of an isolated tear of the PL bundle.

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