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Abbreviations:

ACL = anterior cruciate ligament
SE = spin echo

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Posteromedial Tibial Plateau Injury including Avulsion Fracture of the Semimembranous Tendon Insertion Site: Ancillary Sign of Anterior Cruciate Ligament Tear at MR Imaging¹

PURPOSE: To evaluate posteromedial tibial plateau injuries of or about the semimembranous tendon insertion site and their association with anterior cruciate ligament (ACL) tears on magnetic resonance (MR) images.

MATERIALS AND METHODS: A retrospective study of MR images and conventional radiographs was performed in 10 patients with posteromedial tibial plateau injuries, including avulsion fractures of the semimembranous tendon insertion site. Associated abnormalities were analyzed, including ACL tears, medial meniscal tears, and other lateral femorotibial compartment injuries. Findings from the clinical history and physical examination were correlated with radiographic and MR imaging findings. Nine patients had arthroscopically or surgically documented ACL tears.

RESULTS: All 10 patients had ACL tears at MR imaging. Five patients had posteromedial tibial plateau fractures: Four had avulsion fractures of the tendon insertion site, and one had a fracture lateral to the site. Five patients had posteromedial tibial plateau bruises: Two had bruises at the tendon insertion site. Five patients had tears of the posterior horn of the medial meniscus. Two patients had posterior meniscocapsular separations. Three patients showed evidence of the O'Donoghue triad. Six patients had bruises of the lateral tibial plateau and of the lateral femoral condyle.

CONCLUSION: There appears to be an association between posteromedial tibial plateau injuries and ACL tears. Posteromedial tibial plateau injuries may be predictive of ACL status.

The importance and clinical usefulness of magnetic resonance (MR) imaging in the diagnosis of anterior cruciate ligament (ACL) injuries are well established. Loss of ACL function can cause anterior translation and internal rotation of the tibia, leading to subsequent morbidity and dysfunction of other structures in the knee (1). ACL tears are one of the most common knee injuries (2), and they can be either isolated or, more commonly, combined with additional ligamentous, meniscal, or bone injuries, owing to the complicated mechanisms of injury that include deceleration, hyperextension, anterior dislocation, external rotation and abduction, and internal rotation of the tibia on the femur (3–5). These associated injuries have been well established and include medial collateral ligament and medial meniscal tears (O'Donoghue triad) (6–8), posterolateral tibial plateau fractures, and lateral femoral condylar contusions (9–14).

Little attention has been paid to injuries of the posteromedial tibial plateau. A few investigators (4,11,15) briefly mentioned the presence of osseous abnormalities of the

TABLE 1
Clinical Information

Patient No./ Age (y)/Sex	Mechanism of Injury	Physical Examination		Treatment
		Anterior Drawer Sign	Lachman Test Result	
1/44/M	Basketball	Positive	Positive	ACL repair
2/41/M	Twisting	Positive	Positive	Conservative
3/33/M	Basketball	Positive	Negative	ACL repair
4/24/M	Fall	Positive	Positive	ACL repair
5/40/M	Fall off a ladder	Positive	Positive	ACL repair
6/43/M	Motor vehicle accident	Negative	Positive	Medial collateral liga- ment repair menis- ectomy
7/26/M	Basketball	Negative	Positive	ACL repair
8/32/M	Basketball	Not examined	Not examined	Conservative
9/16/F	Soccer	Negative	Negative	ACL repair
10/44/M	No data	No data	No data	No data

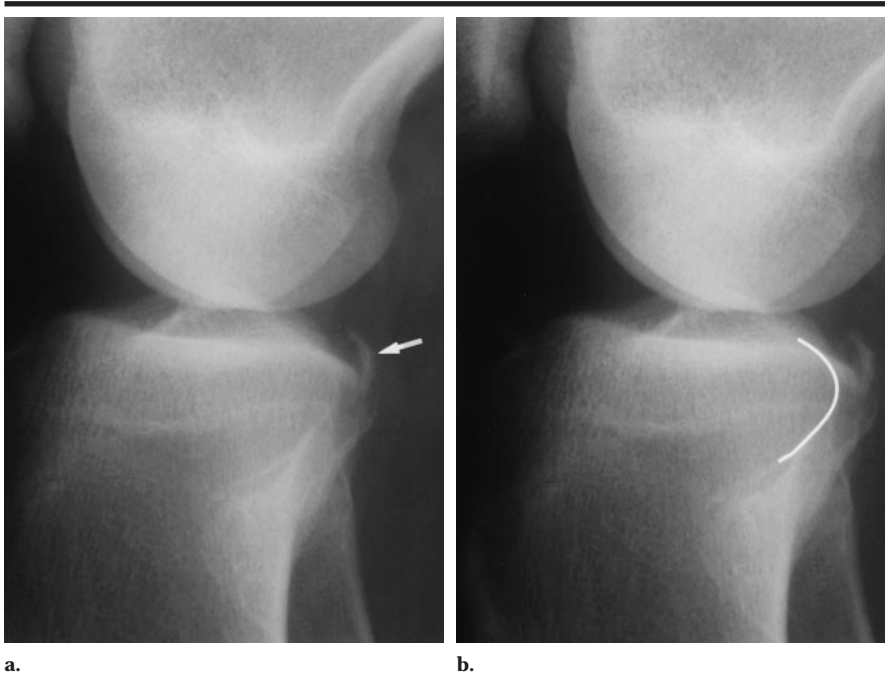


Figure 1. Lateral radiographs of the knee show an avulsion fracture of the posterior tibial plateau. **(a)** Avulsed fracture fragment of the tibia (arrow) is displaced superiorly. **(b)** Avulsed fracture did not occur at the posterior cruciate ligament insertion site because the 7-shaped contour (line) of the posterolateral tibial plateau was not interrupted.

posteromedial tibial plateau when they studied the association of the posterolateral femorotibial compartment and ACL injuries. Two cases of avulsion fracture of the semimembranous tendon insertion site in the posteromedial tibial plateau were found to be associated with ACL tears (16), and, subsequently, one additional case together with findings of a cadaveric study were reported (17). The prevalence and mechanism of these injuries have been debated. The frequency of association of ACL tears to posteromedial tibial plateau injuries in the vicinity of

the semimembranous tendon insertion, however, has not been emphasized. The purposes of this study were to retrospectively investigate posteromedial tibial plateau injuries of or about the semimembranous tendon insertion site, as seen on MR images, and to evaluate their association with ACL tears.

MATERIALS AND METHODS

A retrospective review of all MR images and conventional radiographs of the knee

contained in an MR imaging teaching collection was performed by one author (K.K.C.). All cases that involved an injury of the posteromedial tibial plateau of the semimembranous tendon insertion site, as seen on MR images, were reviewed with another author (D.R.), and a consensus was reached. A total of 10 patients (age range, 16–44 years; average age, 34 years) had evidence of such injuries. Clinical histories, results of physical examination, and treatment strategies were retrospectively reviewed by obtaining the patients' medical records.

MR imaging was performed by using several 1.5-T magnets (Signa, GE Medical Systems, Milwaukee, Wis; Vision, Siemens Medical Systems, Iselin, NJ) with a dedicated extremity coil. Patients were imaged in the conventional supine position. With the four Signa magnets, although pulse sequences varied, in general, the following protocols were used: parasagittal spin-echo (SE) intermediate-weighted (2,300/30 [repetition time msec/echo time msec]), SE T2-weighted (2,300/80), and short inversion time inversion-recovery (3,666/17/150 [repetition time msec/echo time msec/inversion time msec]) sequences; coronal fast SE T1-weighted (500–755/13–20) and fast SE intermediate-weighted fat-saturated (3,000–3,950/18–20) sequences; and axial fast SE intermediate-weighted fat-saturated (3,000–3,950/17–20) sequences or fast SE T2-weighted fat-saturated (3,000/84) sequences.

With the Vision magnet, the following pulse sequences were used: parasagittal fast SE intermediate-weighted (2,500/16), fast SE T2-weighted (2,500/98), short inversion time inversion-recovery (5,300/30/150) sequences; coronal SE T1-weighted (600/14) and fast SE intermediate-weighted fat-saturated (3,000/15) sequences; and axial three-dimensional double-echo steady state sequence (DESS, Siemens Medical Systems; 26/9, 40° flip angle).

The matrix was 256 × 192. Depending on the sequence used, the field of view was either 14 × 14 cm or 15 × 15 cm, and the number of signals acquired was either one or two.

Two authors (K.K.C., D.R.), by using the consensus, analyzed the MR images and classified them by the type of injury to the posteromedial tibial plateau: (a) avulsion fracture of the semimembranous tendon insertion site in the medial tibial plateau, (b) fracture of the medial tibial plateau without avulsion of this insertion site, and (c) bone bruise involving the posteromedial tibial plateau. Other recorded MR findings included the following: presence of an ACL tear, based on

lack of the normal low-signal-intensity band of the ACL in all three planes; meniscal tear, defined by the presence of high signal intensity extending to the surface of the meniscus; meniscocapsular separation, defined by abnormal high signal intensity separating the meniscus and the adjacent capsule; collateral ligament injury, defined by the presence of high signal intensity in or around the ligament and by disruption of the ligament; lateral tibial plateau fractures; and lateral femoral condylar bone bruises. When available, conventional radiographs of the knee and results of arthroscopy or surgery were reviewed.

RESULTS

All patients had acute injuries to the knee related to a sporting activity (particularly basketball), a fall, or a motor vehicle accident. Physical examination revealed knee pain and swelling in all patients. Five patients also had a positive anterior drawer sign and six patients had a positive Lachman test result (Table 1). Five patients, on routine radiographs that had been obtained soon after the injury, had evidence of joint effusion. One patient had a small avulsion fracture of the posteromedial tibial plateau that was seen only on the lateral view (Fig 1a). No additional abnormalities were identified on plain radiographs.

MR images demonstrated more extensive injuries (Table 2). In each of the patients who had evidence of injury to the posteromedial tibial plateau, a complete disruption of the ACL was apparent (Fig 2). The injury to the medial tibial plateau varied slightly. Six patients had injuries of the semimembranous tendon insertion site, including two patients with displaced avulsion fractures, two patients with nondisplaced avulsion fractures, and two patients with bone bruises (Fig 3). The remaining four patients had injuries that were slightly lateral to the central tendon insertion site, including one patient with a fracture and three patients with bone bruises (Fig 4). The displaced avulsion fractures of the insertion site of the central tendon of the semimembranous muscle corresponded to the fractures seen on the plain radiographs. None of the patients had semimembranous tendon ruptures or tears. In addition, seven of the 10 patients also had injuries of the posterior horn of the medial meniscus, including five patients with tears and two patients with meniscocapsular separations.

Other abnormalities seen on the MR images included impaction injuries of the lateral femorotibial compartment (ie, contusions of the lateral femoral condyle and of the posterolateral tibial plateau), which were injuries associated with ACL tears (10,11,15) and which were seen in six of our patients. Three of the 10 patients also had evidence of the O'Donoghue triad: tears of the ACL, the medial meniscus, and the medial collateral ligament.

Nine patients had arthroscopically or surgically documented ACL tears. Arthroscopy had been performed in seven patients. When noted in the arthroscopic reports, meniscal findings correlated with findings on MR images. The presence of meniscocapsular separations was not noted on the arthroscopic reports. Inspection of the posteromedial corner of the knee with regard to the semimembranous tendon was not accomplished. Six patients subsequently underwent surgical repair of the ACL, and one patient underwent repair of the medial collateral ligament with meniscectomy but without ACL repair. This last patient continued to have pain after the surgery and had progression of symptoms and signs related to the ACL tear, including a positive anterior drawer sign and a positive Lachman test result. Two patients were treated conservatively. Clinical information was unavailable in one patient.

DISCUSSION

Bone abnormalities involving the posteromedial tibial plateau are uncommon. To our knowledge, avulsion fractures of the semimembranous insertion site have been described in only three patients (16,17). The frequency of this type of fracture is probably greater, owing to the diagnostic limitations of conventional radiographs in its detection. The fracture is very difficult to detect when the avulsed fragment is not displaced. Even when displaced, a small avulsion fracture can be seen only on the lateral radiograph as a small osseous fragment projecting posterosuperiorly above the tibial plateau.

Unlike posterolateral tibial plateau fractures, which are very often associated with avulsion fractures of the posterior cruciate ligament (18), the 7-shaped contour is not interrupted (Fig 1b). This 7-shaped line is formed by the posterior aspect of the intercondylar tibial cortex and by the posterior aspect of the tibial spine. When this line is interrupted, an avulsion fracture of the posterior cruciate ligament insertion site is suggested. At

TABLE 2
Distribution of Abnormalities at MR Imaging

MR Findings	No. of Patients
Complete ACL tear	10
Avulsion fracture of semimembranous tendon insertion site	4
Bone bruise of semimembranous tendon insertion site	2
Fracture of posteromedial tibial plateau	1
Bone bruise of posteromedial tibial plateau	3
Posterolateral meniscal tear	5
Posteromedial meniscocapsular separation	2
Contusion of lateral femoral condyle	6
Posterolateral tibial bone contusion	6
Medial collateral ligament tear	3
Posterior capsular rupture	1
Lateral meniscal tear	2



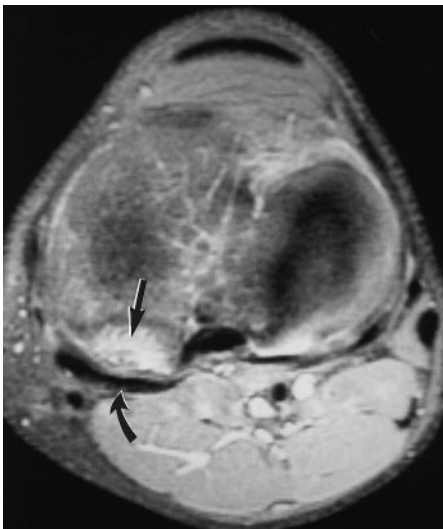
Figure 2. Parasagittal MR image (2,300/30) of the knee demonstrates an avulsion fracture of the semimembranous tendon insertion site. Superior aspect of the ACL (arrows) is torn.

MR imaging, an avulsion fracture or a contusion of the posteromedial tibial plateau can be detected easily.

In several large series (4,11,15) of patients with internal derangements of the knee, the incidence of osseous abnormalities of the posteromedial tibial plateau varied from 0% to 40%, although the importance of the lesions was not addressed. Rosen et al (15) noted that among patients who had an ACL injury, 40% also had injuries to the posteromedial tibial plateau, and 5% had injuries to the me-



a.



b.

Figure 3. Avulsion fracture of the semimembranous tendon insertion site. (a) Parasagittal MR image (2,300/80) of the medial aspect of the knee. Small avulsion (arrows) of the tibia at the semimembranous tendon insertion site. The tendon (arrowhead) is displaced slightly posteriorly with respect to its insertion site. (b) Axial fat-saturated MR image (3,000/17) of the tibial plateau immediately superior to the semimembranous tendon insertion site demonstrates bone edema (straight arrow) in the posteromedial tibial plateau. The semimembranous tendon (curved arrow) is posterior to this area. (c) Axial fat-saturated MR image (3,000/17) of the tibia demonstrates the semimembranous tendon (arrowhead) with a posteriorly displaced insertion site (curved arrow) and adjacent bone (straight black arrow) and soft-tissue (straight white arrow) edema.



c.

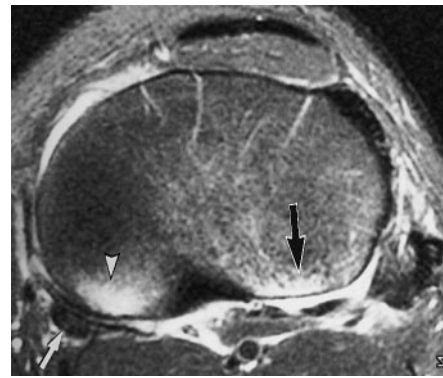


Figure 4. Axial fat-saturated MR image (3,000/84) of the tibial plateau demonstrates edema (arrowhead) in the posteromedial tibial plateau just lateral to the semimembranous tendon insertion site (white arrow) and in the posterolateral tibial plateau (black arrow).

60°–80° of flexion. This resulted in external rotation of the tibia and anterior subluxation of the medial tibial plateau (17), which produced an impaction injury of the medial tibial plateau.

However, our study findings showed that none of the patients had associated impaction injuries of the medial femoral condyle. Therefore, the posteromedial tibial plateau lesions apparently were not related to a compressive force. Instead of a varus force, we believe that a valgus force applied to the tibia most likely causes external rotation and, possibly, anterior subluxation of the tibia in a mechanism similar to the one that leads to a tear of the ACL (1). We suggest, further, that during this injury, as the ACL is torn, the knee subluxates anteriorly and rotates externally, which produces a torque on the posteromedial aspect of the knee. This may lead to an avulsion fracture or a contusion of the posteromedial tibial plateau.

The semimembranous muscle has a complex insertion site in the posterior aspect of the knee (16,19). The central tendon, which is seen at MR imaging as a low-signal-intensity structure, inserts on the infraglenoid tubercle of the posteromedial tibial plateau. In our study, the avulsion fractures occurred at the insertion site of this central tendon. In addition, the semimembranous tendon sends fibers to the posterior capsule, to the posterior horn of the medial meniscus, and to a portion of the capsule that is deep to the medial collateral ligament. Traction on these additional fibers may cause an associated tear of the posterior horn of the medial meniscus, a posterior capsular injury, a meniscocapsular separa-

dial femoral condyle. Speer et al (4) reported a 29% frequency of medial tibial plateau lesions and a 10% frequency of medial femoral condyle lesions in skiers with ACL tears. Kaplan et al (11) reported a 7% incidence of associated medial tibial plateau occult fracture without any medial femoral condylar injuries in patients with ACL injuries. Thus, the frequency of injuries in this portion of the tibia appears to be higher than once thought.

In our 10 patients, an injury to the posteromedial tibial plateau was always associated with an ACL tear. Vanek's (17) cadaveric study findings showed that the ACL was torn before the medial tibial plateau translated anteriorly, which led

to a posteromedial tibial plateau fracture. Therefore, the presence of a fracture of the posteromedial tibial plateau appears to be predictive of an associated ACL tear.

The mechanism leading to this type of injury, however, is not clear. Yao and Lee (16) proposed that an avulsion fracture of the semimembranous tendon insertion site is related to external rotation and abduction of the lower leg when the knee is flexed, perhaps because the semimembranous muscle is both a flexor and an internal rotator of the tibia. However, in Vanek's (17) study, fracture of the semimembranous tendon insertion site or of the adjacent tibial plateau was created by applying a varus force to the knee held in

tion, or a combination of these injuries. In all cases, there was no evidence of the semimembranous tendon tear or rupture. The exact reason for the avulsion fracture of the tibia rather than a semimembranous tendon injury presumably relates to the fact that the tendon itself is stronger than its insertion site.

Bone injuries in the lateral compartment are well-known ancillary signs of a tear of the ACL. In our study, six of 10 patients had concurrent contusions of the lateral femoral condyle and of the posterolateral tibial plateau. The fact that lateral compartment injuries were so closely associated with injury to the posteromedial tibial plateau leads us to suggest that when the ACL is torn, the resultant rotary instability causes both traction to be applied to the medial aspect of the knee and impaction of its lateral aspect. As a result, injuries occur to both the medial tibial plateau and the lateral femorotibial compartment.

There are some limitations to the study. All cases were selected from a teaching file, which probably led to a selection bias. Although our review suggests a definite relationship between posteromedial tibial plateau injury and ACL injury, we did not determine the specificity of the plateau injury with regard to the ACL injury. Furthermore, we did not study the frequency of injury in and around the semimembranous tendon insertion site in patients with ACL injury.

In addition, the small number of cases prevented statistical analysis. Most of the cases did not have conventional radiographic correlation. Furthermore, MR imaging protocols were not uniform. Small, nondisplaced fractures may be missed on MR images and interpreted as only bone marrow edema. Some of these osseous

lesions at the posteromedial aspect of the tibia may also be caused by impaction injuries rather than by avulsion injuries. Owing to the retrospective nature of the study, arthroscopic data were limited, particularly with regard to the presence of meniscocapsular separation or small fractures in the posteromedial corner of the knee.

In summary, our data, derived from an analysis of information from 10 patients, indicate that a fracture of the posteromedial tibial plateau is predictive of an associated ACL tear, although the mechanism leading to this type of bone injury is not clear.

References

1. Remer EM, Fitzgerald SW, Friedman H, Roger LF, Hendrix RW, Schafer MF. Anterior cruciate ligament injury: MR imaging diagnosis and patterns of injury. *Radiographics* 1992; 12:901-915.
2. Mink JH, Deutsch AL, eds. MRI of the musculoskeletal system: a teaching file. New York, NY: Raven, 1990; 251-385.
3. Kennedy JC, Weinberg HW, Wilson AS. The anatomy and function of the anterior cruciate ligament: as determined by clinical and morphological studies. *J Bone Joint Surg [Am]* 1974; 56:223-235.
4. Speer KP, Warren RF, Wickiewicz TL, Horowitz L, Henderson L. Observations on the injury mechanism of anterior cruciate ligament tears in skiers. *Am J Sports Med* 1995; 23:77-81.
5. Feagin JF Jr. The syndrome of the torn anterior cruciate ligament. *Orthop Clin North Am* 1979; 10:81-90.
6. O'Donoghue DH. Surgical treatment of fresh injuries to the major ligaments of the knee. *J Bone Joint Surg [Am]* 1950; 32:721-737.
7. O'Donoghue DH. An analysis of end results of surgical treatment of major injuries to the ligaments of the knee. *J Bone Joint Surg [Am]* 1955; 37:1-12.
8. Staron RB, Haramati N, Feldman F, et al. O'Donoghue's triad: magnetic resonance

- imaging evidence. *Skeletal Radiol* 1994; 23:633-636.
9. Stallenberg B, Gevenois PA, Sintzoff JSA, Matos C, Andrianne Y, Struyven J. Fracture of the posterior aspect of the lateral tibial plateau: radiographic sign of anterior cruciate ligament tear. *Radiology* 1993; 187:821-825.
10. 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; 182:221-224.
11. Kaplan PA, Walker CW, Kilcoyne RF, Brown DE, Tusek D, Dussault RG. Occult fracture patterns of the knee associated with anterior cruciate ligament tears: assessment with MR imaging. *Radiology* 1992; 183:835-838.
12. Cobby MJ, Schweitzer ME, Resnick D. The deep lateral femoral notch: an indirect sign of a torn anterior cruciate ligament. *Radiology* 1992; 184:855-858.
13. Stein LN, Fischer DA, Fritts HM, Quick DC. Occult osseous lesions associated with anterior cruciate ligament tears. *Clin Orthop* 1995; 313:187-193.
14. Mink JH, Deutsch AL. Occult cartilage and bone injuries of the knee: detection, classification, and assessment with MR imaging. *Radiology* 1989; 170:823-829.
15. Rosen MA, Jackson DW, Berger PE. Occult osseous lesions documented by magnetic resonance imaging associated with anterior cruciate ligament ruptures. *Arthroscopy* 1991; 7:45-51.
16. Yao L, Lee JK. Avulsion of the posteromedial tibial plateau by the semimembranous tendon: diagnosis with MR imaging. *Radiology* 1989; 172:513-514.
17. Vanek J. Posteromedial fracture of the tibial plateau is not an avulsion injury: a case report and experimental study. *J Bone Joint Surg [Br]* 1994; 76:290-292.
18. Covey DC, Spapega AA. Injuries of the posterior cruciate ligament. *J Bone Joint Surg [Am]* 1993; 75:1376-1386.
19. Warren F, Marshall JL. The supporting structures and layers on the medial side of the knee: an anatomic analysis. *J Bone Joint Surg [Am]* 1979; 61:56-62.