Is Edema at the Posterior Medial Tibial Plateau Indicative of a Ramp Lesion?

An Examination of 307 Patients With Anterior Cruciate Ligament Reconstruction and Medial Meniscal Tears

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Background: Medial meniscal tears are commonly seen during anterior cruciate ligament reconstruction (ACLR). A subset of these injuries includes posterior meniscocapsular junction or "ramp" tears. One criterion that may correlate with a ramp lesion is the presence of posterior medial tibial plateau (PMTP) edema.

Purpose: To compare patients with ramp lesions to patients with nonramp (meniscal body) medial meniscal tears and correlate PMTP edema on preoperative magnetic resonance imaging (MRI) to the incidence of ramp tears.

Study Design: Case-control study; Level of evidence, 3.

Methods: From 2006 to 2016, a total of 852 patients underwent ACLR and had operative reports available for review. Age, sex, laterality, mechanism of injury (contact/noncontact), sport, revision procedure, multiligament injury, time to MRI, and time to surgery were recorded. Preoperative MRI scans were reviewed for PMTP edema using axial, coronal, and sagittal T2 and proton-density sequences. Differences between groups were analyzed using a 2-sample *t* test and chi-square test. Univariate and multivariate logistic regression models examined correlations with tear type.

Results: Overall, 307 patients had medial meniscal tears identified during ACLR (127 ramp lesions, 180 meniscal body lesions). The ramp group was 7.5 years younger than the meniscal body group ($P < .01$). The groups were not different regarding sex, contact injury, revision surgery, laterality, or multiligament injury. Patients with delayed ACLR were significantly more likely to have a meniscal body tear than a ramp lesion (odds ratio, 3.3 [95% CI, 1.9-5.6]; $P < .01$). The sensitivity of PMTP edema for a ramp tear was 66.3%, and 54.5% of patients with ACLR and a medial meniscal tear had PMTP edema. Patients with PMTP edema were significantly more likely to have a ramp tear than a meniscal body tear (odds ratio, 2.1 [95% CI, 1.1-4.1]; $P < .03$).

Conclusion: The overall incidence of ramp tears in patients undergoing ACLR was 14.9%, and these tears were more prevalent in younger patients. Meniscal body tears were significantly more likely than ramp tears with delayed ACLR. In patients undergoing ACLR with an associated medial meniscal tear, the presence of PMTP edema demonstrated significantly greater odds for ramp lesions compared with meniscal body tears.

Keywords: meniscus; meniscocapsular tear; tibial contusion; MRI

Peripheral tears of the posterior horn medial meniscus are commonly seen in patients with anterior cruciate ligament (ACL) disruption. In a prospective analysis of 476 patients with both ACL and meniscal tears, peripheral posterior horn medial meniscal tears occurred in 40% of cases.[21] A subset of these injuries includes lesions at or adjacent to the posterior meniscocapsular junction, called ramp lesions, which occur in 3.1% to 23.2% of patients with ACL disruption.[10,14,16,21] These lesions can be difficult to diagnose with magnetic resonance imaging (MRI) or arthroscopically.[16,18,19] This is particularly concerning when considering that biomechanical studies have indicated that ramp injuries may compromise anterior stability of the knee.[1,24] However, the clinical implications of these biomechanical changes is currently under investigation.[15]

Multiple authors have demonstrated the utility of a posteromedial portal or 70° arthroscope to improve the detection of these injuries.[3,6,23,26] It has also been suggested that a probe be utilized to thoroughly examine the posterior meniscocapsular junction to avoid missing a hidden

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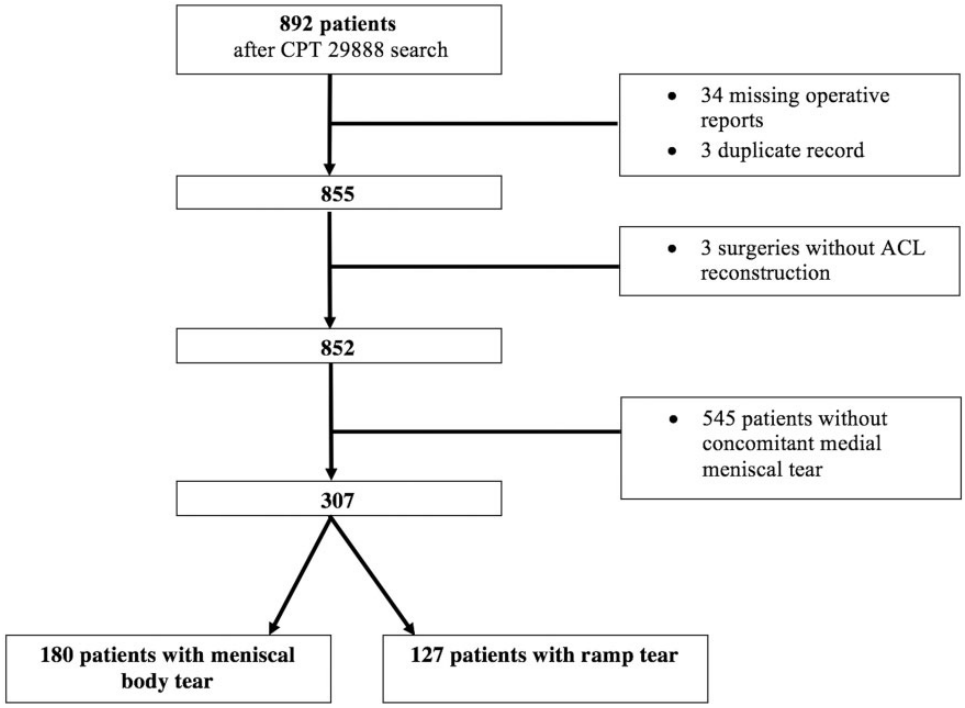

Figure 1. Diagram of included and excluded patients after an initial search for anterior cruciate ligament (ACL) reconstruction with Current Procedural Terminology (CPT) code 29888.

tear.[2,10] The development of diagnostic MRI criteria to aid in the preoperative diagnosis of ramp tears is currently under investigation.[5,9,10,12] Such criteria include the presence of fluid between the meniscus and medial collateral ligament (MCL), an abnormal meniscal outline, and an increased distance between the MCL and meniscus.[9] While these criteria may be helpful, the positive predictive value (PPV) of MRI in detecting posteromedial meniscocapsular junction has been demonstrated to be extremely low.[5,16,19] Developing additional MRI criteria may be useful to accurately detect these injuries.

One criterion in particular that shows promise is the presence of medial tibial plateau edema, which is used to help detect adjacent meniscal tears.[12] Kaplan et al[13] described a correlation between posterior medial tibial plateau (PMTP) edema and peripheral posterior horn medial meniscal injuries, which may be the result of an impaction injury as the knee reduces immediately after the ACL is torn. If the identification of PMTP edema could indicate a strong possibility of a ramp lesion, this may prevent missed injuries. The purpose of the present study was (1) to compare patients with ramp lesions to patients with other variants of medial meniscal tears and (2) to determine the utility of PMTP edema in preoperative MRI for the diagnosis of a ramp tear.

METHODS

Institutional review board approval was obtained for this investigation. A retrospective chart review was conducted on all patients who underwent ACL reconstruction (ACLR) by 1 of 2 senior authors (R.A.A. and C.E.) between January 2006 and June 2016. A single-institution database search for Current Procedural Terminology (CPT) code 29888 initially identified 892 patients with ACL surgery during the study period (Figure 1). Patients without available operative records were then excluded.

Operative notes identified patients diagnosed arthroscopically with a medial meniscal injury of any kind, including tears at the posterior medial meniscocapsular junction. Regardless of preoperative MRI findings, both senior surgeons routinely inspected the posteromedial compartment during ACL surgery via the modified Gillquist maneuver[11]

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Ethical approval for this study was obtained from the University of Connecticut Health Center.

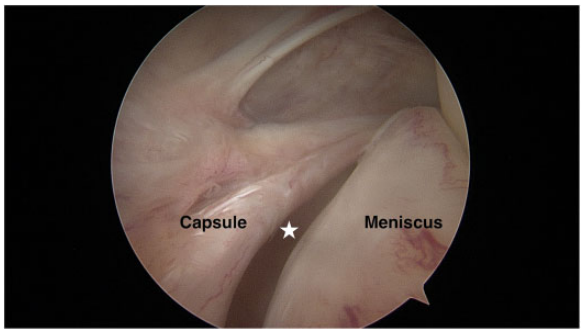

Figure 2. The posteromedial compartment of a right knee is examined using the modified Gillquist maneuver from the anterolateral portal and a 70° arthroscope. A ramp tear (star) is easily appreciated with separation of the capsule from the posterior horn medial meniscus.

(Figure 2). If a lesion was not immediately apparent, an 18-gauge spinal needle was used to probe the peripheral posterior horn medial meniscus and meniscocapsular junction to detect the presence or absence of ramp injuries. For the purposes of this investigation, arthroscopic identification was the gold standard for diagnosis; no patient was considered positive for a medial meniscal tear by MRI findings alone. Similar to Sonnery-Cottet et al,[23] medial meniscal tears that were not ramp lesions were considered tears of the meniscal body.

For patients who underwent ACLR and had concomitant medial meniscal tears, demographic information such as age, sex, laterality, mechanism of injury (contact/noncontact), sport, revision procedure, multiligament procedure, time to MRI, and time to surgery were recorded. Revision and multiligament procedures were included to encompass all patients with ACL abnormalities. For this investigation, MRI was considered delayed if performed after 8 weeks from the date of injury. Similarly, time to surgery was considered delayed if the period was longer than 8 weeks from the date of injury. Preoperative MRI scans were obtained for all patients undergoing ACLR and reviewed in a single reading by an orthopaedic sports medicine fellow (N.S.K.) for edema of the PMTP. The fellow was blinded to the type of medial meniscal tear diagnosed arthroscopically. Axial, coronal, and sagittal T2 and proton-density sequences were reviewed (Figure 3) to identify PMTP edema, which was considered positive if it was detected in at least 2 different planes of T2 sequences. Many patients had MRI performed at outside facilities, which did not denote the magnet quality; therefore, this information was not recorded.

Descriptive statistics, including the mean and SD for continuous data and frequency and proportion for categorical data, were calculated to characterize the study group. Differences in age between those who had a ramp tear and those who did not were examined with a 2-sample t test. Differences between the 2 groups in categorical variables were examined with the chi-square or Fisher exact test where appropriate. Univariate and multivariate logistic regression models were used to explore the relationships among patient factors, MRI findings, and the occurrence of a ramp lesion. Analyses were calculated with 95% CIs, and the alpha level was set at .05. All analyses were performed with Stata 15.0 (StataCorp).

RESULTS

Operative reports were available for review in 852 patients. The mean age for the overall cohort was 28.6 years (range, 8-68 years), which consisted of 470 male and 382 female patients. Injury laterality was almost equal between left (n = 430) and right (n = 422) knees. From this cohort, 186 revision procedures and 121 multiligament injuries were included for investigation.

Medial Meniscal Tear

Overall, 307 patients (Table 1) were diagnosed with a medial meniscal tear at the time of ACLR, which is an incidence of 36.0%; 68.7% of patients with ACLR and medial meniscal tears sustained an injury during participation in sports, with soccer (17.3%), basketball (15.3%), and football (8.8%) being the most common. Also, 24.8% had

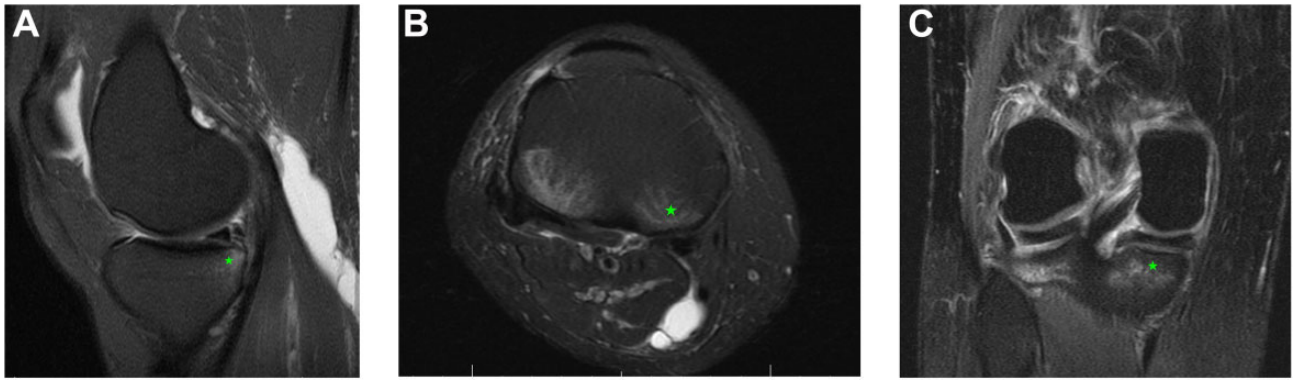

Figure 3. (A) Sagittal, (B) axial, and (C) coronal T2 magnetic resonance imaging sequences after an anterior cruciate ligament injury. Edema of the posterior medial tibial plateau (green star) is evident in all 3 planes.

TABLE 1
Demographics and Characteristics of Patients With Anterior Cruciate Ligament Deficiency and Medial Meniscal Tears

	All	Meniscal		*P* Value
		Ramp	Body	
Mean age, y	29.2	24.8	32.3	<.01
Sex, n				.82
Male	179	75	104	
Female	128	52	76	
Laterality, n				.71
Right	161	65	96	
Left	146	62	84	
Contact, n				.67
Yes	45	21	24	
No	236	102	134	
Unknown	26	4	22	
Revision, n				.32
Yes	64	30	34	
No	243	97	146	
Multiligament, n				.38
Yes	23	7	16	
No	284	120	164	
Time from injury to surgery, n				<.01
<8 wk	83	51	32	
>8 wk	184	60	124	
Unknown	40	16	24	

knee injuries that were not sports related, and 6.5% did not specify; 76.9% of patients reported a noncontact mechanism of injury, compared with 14.7% who sustained a contact injury and 8.5% with an unspecified mechanism.

Ramp Lesion Versus Meniscal Body Lesion

At the time of ACLR, 127 patients were diagnosed with a ramp lesion. The overall incidence of ramp tears was 14.9% and consisted of 41.4% of all medial meniscal tears. Patients in the ramp group were a mean 7.5 years younger ($P < .01$) than patients with meniscal body tears (Table 1). The groups were not statistically different with regard to sex, laterality, mechanism of injury (contact/noncontact), revision procedure, or multiligament procedure. Patients with medial meniscal tears who underwent acute ACLR were significantly more likely ($P < .01$) to have ramp tears (61.4%) compared with meniscal body tears (38.6%). On the other hand, patients with delayed surgery were significantly more likely ($P < .01$) to have meniscal body tears (67.4%) versus ramp lesions (38.6%). Patients with delayed ACLR had 3.3 times greater odds (95% CI, 1.9-5.6; $P < .01$) of having a meniscal body tear compared with a ramp lesion.

The time from injury to MRI was available in 86.6% of patients with ramp tears and 77.2% of patients with meniscal body tears. MRI was more likely to be delayed (>8 weeks from injury) in the meniscal body group (44.6%) compared with the ramp group (23.6%) ($P < .01$).

PMTP Edema

MRI scans were available for review in 178 patients, which consisted of 63.0% of the ramp group and 54.4% of the meniscal body group; 54.5% of patients with an ACL injury and medial meniscal tear had PTMP edema. The PPV of PMTP edema for ramp tears was 54.6%. Of the 80 patients with ramp tears and available MRI scans, 66.3% had PMTP edema. Of the 98 patients with meniscal body tears and available MRI scans, 44.9% had PMTP edema.

Of the 97 patients with PMTP edema, 54.6% had ramp lesions and 45.4% had meniscal body tears ($P < .01$). Patients with preoperative MRI scans positive for PMTP edema had 2.5 times greater odds (95% CI, 1.4-4.6; $P < .01$) of having a ramp lesion compared with a meniscal body lesion. A multivariate regression model was used to correct for the difference in delayed MRI between the 2 groups. This analysis revealed that patients with PMTP edema had 2.1 times greater odds (95% CI, 1.1-4.1; $P < .03$) of having a ramp lesion compared with a meniscal body lesion.

DISCUSSION

To our knowledge, this is the largest study to compare patients with medial meniscal ramp tears to those with medial meniscal body lesions in the setting of ACL injuries. In our cohort of 852 patients with an ACL injury, 14.9% were diagnosed with ramp tears at the time of surgery. Historical reports describe ramp tears occurring in up to 20.9% of patients with ACL tears[27]; however, more recent large cohort studies have suggested a slightly lower incidence of 15.8% to 16.6%.[14,22] Malatray et al[16] actually found a much higher incidence rate of 23.2% in an adolescent population with a mean age of 14 years. Our cohort was older (24.8 years) and more similar to studies that included both pediatric and adult patients.[10,14,22,23] However, the results of this investigation do support the notion that ramp lesions occur more often in younger patients, as we found that patients with ramp lesions were more than 7 years younger than patients with meniscal body tears. Liu et al[14] also found that ramp lesions were more prevalent in younger patients in their review of 868 primary ACLRs. In their study, 79% of ramp tears occurred in patients younger than 30 years. We hypothesize that younger patients may be more likely to sustain ACL tears during higher demand activities, such as sports that involve cutting, pivoting, and lateral movement. This may result in a higher energy mechanism of injury, leading to a greater risk of capsular trauma. In our study, a larger percentage of patients with ramp tears sustained injuries from a sporting event, contact injury, or multiligamentous knee injury compared with the percentage of patients with meniscal body tears. However, none of these differences were statistically significant.

In a review of the MOON (Multicenter Orthopedic Outcomes Network) and MARS (Multicenter ACL Revision Study) data, Borchers et al[7] found new medial meniscal tears in 40% of patients in both the primary and revision ACLR groups. In our cohort, medial meniscal tears

occurred at a similar rate in primary (33.0%) and revision (35.0%) cases. We suspected that tear type (ramp versus meniscal body lesions), would be different in primary cases compared with revision cases. However, we did not find a statistical difference. Medial meniscal tears were more likely to be meniscal body lesions in both primary (60.1%) and revision (53.1%) cases. The minority of ramp tears (23.6%) occurred in the setting of revision ACLR, which is a similar percentage to that found by DePhillipo et al.[10]

Delayed ACLR is a known risk factor for the development of medial meniscal tears.[4,20,25] Previous reports have also supported the notion that ramp tears are more likely to occur in patients with delayed ACL stabilization.[14,17,27] This investigation found similarly; 54.1% of patients with ramp tears underwent ACLR more than 8 weeks from injury. However, our data suggest that chronic ACL deficiency is much more relevant to the development of meniscal body tears than peripheral tears of the meniscocapsular junction. Surgery beyond 8 weeks from injury resulted in almost a 4-fold increased rate of meniscal body lesions. It is important for the ACL surgeon to recognize that medial meniscal lesions may be more centrally located if surgery is delayed. Secondarily, the healing potential of such tears may also be reduced if the rate of peripheral red-red and meniscocapsular tears is lowered and the rate of red-white or white-white tears is increased.[2]

The biomechanical consequences of ramp tears and the effect of repair with regard to ACLR outcomes have yet to be fully elucidated. Ahn et al[1] reported that ramp tears increased anterior tibial translation by 48% to 101% in ACL-deficient cadaveric knees. Ramp repair restored instability to that seen in isolated ACL-deficient knees. Stephen et al[24] noted increased anterior tibial translation and external rotation with ramp lesions in ACL-deficient knees. Isolated ACLR did not restore knee stability, but reconstruction plus ramp repair did reduce laxity to baseline values. In our own laboratory (unpublished data, 2017), we have found ramp tears to result in greater ACL strain at 30° and 90° of flexion and ramp repair to reduce ACL strain by 30% to 40% at 0°, 30°, 60°, and 90°. Based on clinical experience and the work performed in our own laboratory, it is the opinion of the senior authors that ramp repair confers a degree of stabilization and protection to the ACL graft. The recognition of such lesions may be especially critical because ramp tears occur in up to 15% of patients undergoing ACLR.[23]

Currently, to our knowledge, there exists no set of criteria that can reliably diagnose or exclude the presence of ramp lesions based on preoperative MRI. An irregular posterior meniscal outline and perimeniscal fluid signal separating the meniscus and capsule, particularly on T2 sagittal images, are often considered to correlate best with the diagnosis of a ramp lesion.[8,9,12] However, such findings may also be confused with normal anatomy. Rubin et al[19] attempted to use other findings to increase the diagnostic utility of MRI, but meniscal displacement, meniscocapsular signal change, and fluid around the MCL all had PPVs less than 11%.

Edema of the PMTP has been reported to correlate with the presence of ramp tears in smaller cohort studies. In 25 patients with positive PMTP edema, Kaplan et al[13] noted that 14 patients had meniscocapsular injuries and 10 had peripheral posterior medial meniscal tears confirmed with arthroscopic surgery. We also found PMTP edema to correlate with peripheral tears. Patients with PMTP edema present on preoperative MRI had 2.1 times greater odds of a diagnosis of a ramp lesion compared with more central meniscal body tears. Additionally, a greater percentage of patients with ramp tears had PMTP edema on preoperative MRI than did patients with meniscal body tears. More recently, DePhillipo et al[10] reported on 50 patients with arthroscopically proven ramp tears, 72% of whom had PMTP edema on preoperative MRI. Arner et al[5] found that combining perimeniscal fluid signal and PMTP edema resulted in excellent specificity and negative predictive value in diagnosing 13 ramp tears; however, the sensitivity and PPV were much more varied. In our large cohort, PMTP edema was 66.3% sensitive for ramp lesions, similar to the results of DePhillipo et al[10] and Arner et al.[5] Ultimately, however, PMTP edema as an isolated finding has only moderate utility to diagnose or exclude ramp tears, with a sensitivity and PPV between 55% and 66%.

Limitations

One of the major limitations of this study was that MRI was more likely to be delayed longer than 8 weeks after injury in patients with meniscal body tears compared with patients with ramp tears. PMTP edema that occurred at the time of injury could have resolved during such a delay, which would have resulted in a falsely negative MRI finding. We did find, however, that 27.8% of patients with PMTP edema had delayed MRI. Furthermore, after multivariate analysis, patients with PMTP edema were still more than twice as likely to have ramp tears versus meniscal body tears. Only 59% of patients with ACL and medial meniscal tears had preoperative MRI scans available for review. The unavailable MRI scans may have led to different findings regarding PMTP edema and its correlation to either ramp or meniscal body tears compared with the imaging scans that we reviewed.

Ramp lesions were diagnosed by an arthroscopic examination of the posteromedial compartment; however, the senior surgeons may have used different criteria to classify these tears. Medial meniscal tears in patients may have been missed during ACLR, although in our opinion this risk is low, considering that both senior surgeons routinely inspect the medial meniscus for meniscal body and ramp tears. In addition, MRI scans were not studied in patients without medial meniscal tears, as this investigation focused on identifying PMTP edema for ramp versus meniscal body tears in patients undergoing ACLR. Finally, ACLRs that were not coded using CPT 29888 would have been missed during patient record collection, and incomplete patient and operative records may have negatively affected our results as well.

CONCLUSION

In our cohort of 852 patients, the overall incidence of ramp tears was 14.9%, and such tears were more prevalent in younger patients. Delayed ACLR resulted in 3.3 times greater odds of meniscal body tears compared with ramp tears. There was no statistical difference between the groups with regard to laterality, mechanism of injury, revision surgery, or multiligament injury. Patients with PMTP edema on preoperative MRI had 2.1 times greater odds of having ramp lesions compared with meniscal body tears at the time of ACLR.

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