

A Prospective Magnetic Resonance Imaging Study of the Incidence of Posterolateral and Multiple Ligament Injuries in Acute Knee Injuries Presenting With a Hemarthrosis

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Purpose: The purpose of this study was to determine whether the incidence of posterolateral knee injuries, as well as other concurrent knee ligament injuries, could be obtained from a prospective evaluation of magnetic resonance imaging scans in patients with an acute knee injury with a hemarthrosis. **Methods:** We prospectively documented all patients with acute (within 30 days) knee injuries with a hemarthrosis over a 90-day period who underwent 1.5-T magnetic resonance imaging at a large referral imaging facility with 6 sites, effectively covering a large metropolitan area. The anterior cruciate ligament, superficial medial collateral ligament, and posterior cruciate ligament (PCL) and the following individual structures of the posterolateral corner were evaluated for high-grade injury: fibular collateral ligament, popliteus tendon, and popliteofibular ligament. **Results:** Out of 331 consecutive acute knee injuries with a hemarthrosis, 265 ligament injuries occurred in 187 patients (56%). Of these 187 patients with ligament injuries, 126 had isolated ligament injuries and 61 (33%) had combined multiple ligament injuries. Of the 187 patients with knee ligament injuries, 83 (44%) had isolated anterior cruciate ligament tears, 28 (15%) had isolated superficial medial collateral ligament tears, 11 (5%) had isolated PCL tears, and 4 (2.1%) had isolated posterolateral knee tears. Of the patients with posterolateral knee structure injuries, 87% (26/30) had multiple ligament injuries, with the overall incidence of posterolateral knee injuries among all knee ligament injuries being 16% and among all acute knee injuries with a hemarthrosis being 9.1%. Of the 27 patients with PCL tears, 16 (52%) had combined multiple ligament injuries. **Conclusions:** This study shows that in this population, the incidence of posterolateral knee injuries in patients with acute knee ligament injuries with a hemarthrosis was 9.1%. It also verified that most PCL and posterolateral corner injuries occur in combination with other ligament injuries. **Level of Evidence:** Level II, development of diagnostic criteria on the basis of consecutive patients with a universally applied gold standard. **Key Words:** Posterolateral knee—Multiple ligament knee injuries—Magnetic resonance imaging—Incidence.

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Posterolateral knee and multiple ligament injuries can be very difficult to diagnose and treat in a patient with an acute knee injury.¹⁻⁴ A diagnosis of posterolateral instability can usually be attained by a careful interpretation of specific clinical examination techniques^{3,4} and can be supplemented by direct visualization with arthroscopy in those patients in whom a diagnosis is still in doubt.⁵ Pain and guarding are often associated with an acute injury and can mask clinical examination findings.⁵ Interpretation of examination findings can also be difficult when posterolateral knee injuries occur in the setting of a multiple ligament

injury.⁶⁻⁹ Because of the difficulty of obtaining an accurate clinical examination in the acute setting, the incidence of such injuries is not well understood,^{2,3} and these injuries may go unrecognized until they present as a chronic problem.^{3,10,11} Chronic grade III posterolateral knee injuries in the context of multiple ligament injuries can cause a significant loss of function and contribute to cruciate ligament reconstruction graft failure.^{3,8,12-15} Early treatment of these injuries is associated with improved objective, subjective, and functional outcomes.^{10,16} Recently, new diagnostic protocols have been developed to improve the diagnosis of posterolateral knee injuries with high-resolution magnetic resonance imaging (MRI) scans.^{12,17-20} These new imaging protocols have been shown to be both sensitive and specific for most posterolateral structures with specific imaging techniques that include thin-slice coronal oblique scans along the course of the popliteus tendon and including the entire fibular head and styloid.¹²

Although injuries of the knee often involve multiple structures, detailed descriptions of combined ligament injury profiles are relatively uncommon in the literature. Injuries to the posterolateral corner (PLC) have usually been reported to occur concurrently with cruciate ligament, meniscal, and other structural injuries.^{7,9,21} A thorough understanding of which injury profiles include posterolateral injuries may increase the sensitivity of the clinical diagnosis by raising the level of suspicion when a more common ligament injury is found.

Although it has been frequently reported that the incidence of posterolateral knee injuries is probably under-reported,^{3,4,8,10,17} it is difficult to obtain prospective incidence studies for many reasons. First, studies that rely on patients who present to an emergency department for treatment would probably underestimate the true incidence of posterolateral knee injuries not only because of a potential limited examination acutely because of pain and swelling, but also because the physicians who staff these facilities may not be familiar with the specific knee physical examination techniques necessary to diagnose these injuries. Second, many patients with acute knee injuries may not present to an emergency department for treatment. In addition, patients who present to a sports medicine physician's office have probably been pre-selected because of their higher-grade knee injuries and would potentially result in overestimation of the true incidence of these injuries because other acute knee injuries may be identified and initially treated by

their primary care or general practice orthopaedic physicians.

For these reasons, we believed that the best way to estimate the incidence and associated injury profiles of posterolateral knee injuries would be to obtain a prospective study of all acute knee injuries with a hemiarthrosis that presented to a major MRI referral center with multiple sites that covered a large metropolitan area. It is the accepted standard in our community for internists, family practitioners, and orthopaedists to obtain MRI scans in almost all patients with acute knee injuries with a hemiarthrosis. Our hypothesis was that the incidence of posterolateral knee injuries is higher than has been reported in previous publications. Therefore, the purpose of this study was to document the incidence of posterolateral knee injuries and the concurrent related injury profiles with posterolateral knee injuries in a prospective study of a consecutive group of patients with an acute knee injury with a hemiarthrosis in whom an MRI scan was obtained. In addition, our secondary purpose was to identify the number of other major ligament and combined ligament injuries present in this subset of patients.

METHODS

Approval for this project was obtained through the Human Use Institutional Review Board at the University of Minnesota, Minneapolis, MN. All patients with acute (within 30 days) primary knee injuries who underwent MRI scans over a 90-day period were prospectively identified. All patients who had knee MRI scans obtained during this time filled out the reason for their examination and the date of injury, verified that they had some swelling of their knee within 24 hours of their injury, and indicated whether they had a previous injury or surgery to their knee. Patients with a previous history of ipsilateral knee injury or surgery were not included in this study. A total of 6 MRI locations were used, representing coverage of most of a metropolitan area of 2.5 million persons.

A standard quadrature knee coil was used to collect the images. MRI was performed with a 1.5-T MRI unit (Siemens Vision; Siemens, Erlangen, Germany). The MRI protocol chosen for this study used axial, sagittal, and coronal turbo spin-echo proton-density and T2-weighted sequences (repetition time, 300 milliseconds; echo times, 16 and 98 milliseconds; slice thickness, 3 mm; slice gap, 0.3 mm, field of view, 25 cm × 25 cm; matrix, 380 × 512). High-resolution

T1-weighted sections (repetition time, 685 milliseconds; echo time, 20 milliseconds; slice thickness, 2 mm; slice gap, 0.2 mm; field of view, 25 cm × 25 cm; matrix, 350 × 512) were also acquired in the coronal oblique plane, angled 30° proximoventrally to lie parallel to the lateral intra-articular portion of the popliteus tendon.¹²

A total of 331 patients with acute knee injuries with a hemarthrosis were identified during the study period. All images were read by 1 of 2 sports medicine musculoskeletal radiologists (H.F. and C.G.), who filled out an acute knee injury data sheet on all patients. Tears of the anterior cruciate ligament (ACL), superficial medial collateral ligament (MCL), posterior cruciate ligament (PCL), and the main static stabilizing structures of the PLC—the fibular collateral ligament (FCL), popliteus tendon (PLT), and popliteofibular ligament (PFL)—were specifically scrutinized for complete high-grade tears.^{4,12,15,21-25} For the purposes of this study, a knee with a complete tear of any of the main posterolateral structures (or any combination thereof) was counted as a posterolateral knee injury. A high-grade tear of a specific structure was defined as an avulsion of its attachment to bone or an intrasubstance loss of continuity of the structure’s normal low signal intensity. Injuries considered to be partial (low-grade) tears of structures were not reported on in this study. Multiple ligament injuries were classified into 2-, 3-, or 4-structure groups (ACL, PCL, MCL, or PLC and all possible combinations).

One-way analyses of variance were performed to determine whether there was a difference in the age groups and in gender for the incidence of ligament injury, multiple ligament injury, or PLC injury. Statistical significance was determined to be present for $P < .05$.

RESULTS

Out of a total of 331 patients (mean age, 28.6 years) with acute knee injuries with a hemarthrosis, 187 (56%) had a ligament injury (Table 1 and Fig 1). Patients were categorized into 1 of 4 age groups (≤ 17

TABLE 1. Analysis of Ligament Injury Patterns Identified on MRI Scans in 331 Acute Knee Injury Patients

Ligament Injury Pattern	n	%
No ligament injury	144	44
Single ligament	126	38
Multiple ligaments	61	18

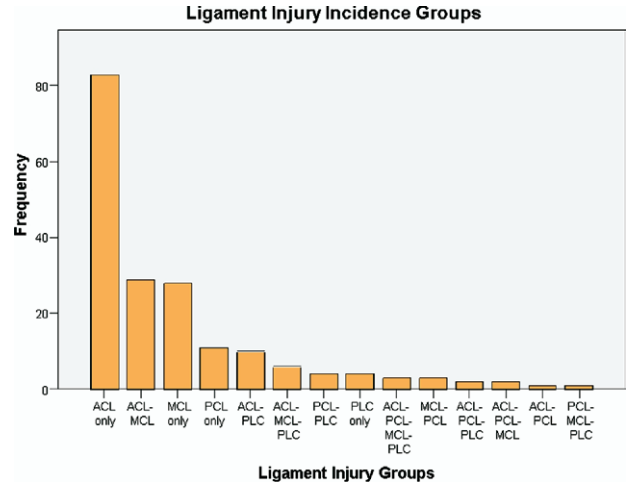


FIGURE 1. Knee ligament tear combinations in 187 patients with acute knee injuries.

years, 18 to 26 years, 27 to 39 years, and ≥ 40 years). There were no significant differences between the age groups and the mean values for any of the previously mentioned injuries.

ACL Tears

Of the 187 patients with acute knee ligament injuries, 136 (74%) had an ACL tear. Of the overall group of 331 patients with acute knee injuries with a hemarthrosis, 41.1% had ACL tears. With regard to ACL tears, 53 (39%) occurred as part of a multiple ligament injury (either 2-, 3-, or 4-component injuries) (Table 2). Of the patients with 2-ligament injuries involv-

TABLE 2. Breakdown of Ligament Tears of 187 Patients With Acute Knee Ligament Injuries Identified on MRI

	n	%
ACL only	83	44
ACL-MCL	29	16
MCL only	28	15
PCL only	11	6
ACL-PLC	10	5
ACL-MCL-PLC	6	3
PCL-PLC	4	2
PLC only	4	2
MCL-PCL	3	2
ACL-PCL-MCL-PLC	3	2
ACL-PCL-MCL	2	1
ACL-PCL-PLC	2	1
ACL-PCL	1	0.5
PCL-MCL-PLC	1	0.5
Total	187	100

TABLE 3. Pattern of Posterolateral Knee Structure Injury in 30 Patients With Acute Tears Identified on MRI

	n	%
PLC component injury breakdown		
FCL-PLT	4	13
FCL-PFL	5	17
PLT-PFL	3	10
FCL-PLT-PFL	5	17
FCL only	4	13
PLT only	5	17
PFL only	4	13
Total	30	100

ing the ACL, 29 had ACL-MCL injuries, 10 had ACL-PLC injuries, and 1 had an ACL-PCL injury. The most frequent 3-ligament combined ACL injury pattern was a combined ACL-MCL-PLC tear (6 patients). This was followed by ACL-PCL-PLC and ACL-PCL-MCL tear combinations, both of which occurred in 2 patients. Of the 136 patients with ACL injuries, 3 had torn all 4 ligaments (ACL-PCL-MCL-PLC).

MCL Tears

The MCL was injured in 72 (39%) of the 187 ligament-injured patients and in 21.8% of the overall group of 331 patients with acute knee injuries with a hemarthrosis. Of the MCL injuries, 61% (44/72) occurred in the setting of a multiple ligament injury (Table 2). The most common combined MCL injury was the ACL-MCL combination (29 patients). A combined MCL-PCL injury occurred in 3 patients. Of the patients tearing 3 ligaments with a combined MCL component, 6 injured the ACL-MCL-PLC, 2 injured the ACL-MCL-PCL, and 1 injured the PCL-MCL-PLC.

Posterolateral Knee Tears

Posterolateral knee injuries occurred in 30 (16.0%) of the 187 patients with acute ligament injuries and in 9.1% of the overall group of 331 patients with acute knee injuries with a hemarthrosis. There were 18 FCL tears, 17 PFL tears, and 17 PLT tears (Table 3). More than half of the PLC injuries (56% [17/30]) involved more than 1 of the 3 evaluated PLC ligaments (Table 4). Single posterolateral structure tears occurred in the PLT in 5 patients, in the FCL in 4, and in the PFL in 4. In patients with multiple PLC structure injuries, the most common injury combination was FCL-PFL tears, which occurred in 17% (5/30) of these patients.

Injuries to the FCL-PLT occurred in 13% (4/30 of patients), and PLT-PFL injuries occurred in 10% (3/30). All 3 structures (FCL-PLT-PFL) were injured in 5 patients. Of the single posterolateral structure tears, the PLT was the only posterolateral ligament to be torn without any other associated ligament injury (2 patients).

Of the patients with PLC structure tears, 87% (26/30) had multiple ligament injuries (Fig 2). Seventy percent of patients with posterolateral structure injuries had a combined ACL tear (Table 4).

PCL Tears

Of the 187 patients with acute ligament tears, 27 (14.4%) had PCL tears. For the overall group of 331 patients with acute knee ligament injuries with a hemarthrosis, 8.2% had acute PCL tears. Of these 27 patients, 16 (59.3%) with PCL tears had combined multiple ligament tears (Table 2). A combined PCL-PLC tear was the most frequent acute ligament tear combination, occurring in 4 patients. The next most frequent PCL tear combinations were MCL-PCL tears and ACL-PCL-PLC-MCL tears, with 3 patients each, and ACL-PCL-MCL tears and ACL-PCL-PLC tears, with 2 patients each. One patient each had combined ACL-PCL tears and PCL-MCL-PLC tears.

TABLE 4. Breakdown of Concurrent Posterolateral Knee Structure and Associated Knee Ligament Tears Identified on MRI

PLC Injury	Frequency
ACL-FCL	3
ACL-MCL-FCL-PFL	2
ACL-PCL-MCL-FCL-PLT	2
ACL-FCL-PLT-PFL	2
ACL-PFL	2
FCL-PFL	2
PLT	2
ACL-FCL-PFL	1
ACL-MCL-FCL	1
ACL-MCL-FCL-PLT-PFL	1
ACL-MCL-PFL	1
ACL-PCL-MCL-PFL	1
ACL-MCL-PLT-PFL	1
ACL-PCL-FCL-PLT-PFL	1
ACL-PCL-PLT	1
ACL-PLT	1
ACL-PLT-PFL	1
PCL-FCL-PLT	1
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PCL-MCL-FCL-PFL	1
PCL-PLT	1
PCL-PLT-PFL	1

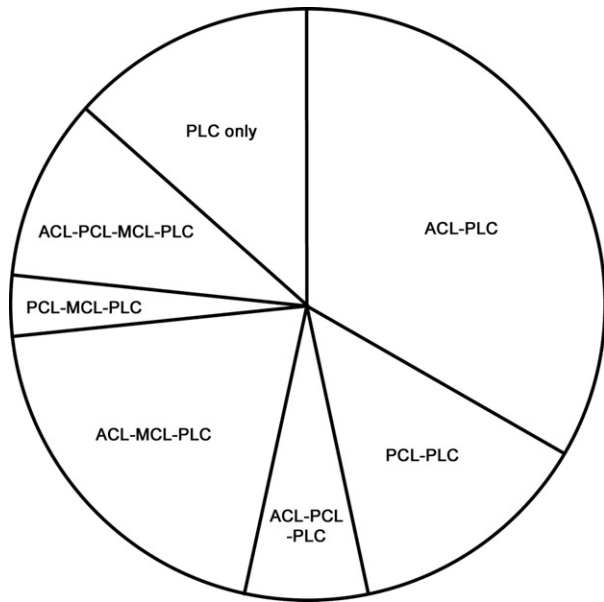


FIGURE 2. Breakdown of posterolateral knee injury patterns in 30 patients with acute injuries.

Multiple Ligament Injuries

Overall, multiple ligament injuries accounted for 33% (61/187) of all patients with ligament injuries (Table 1) and occurred in 18.4% of the 331 patients with acute knee ligament injuries with a hemarthrosis. Two-ligament tears accounted for 25% of the ligament-injured patients overall, three-ligament tears accounted for 6%, and 3 patients had tears of all four ligaments (ACL, PCL, MCL, and PLC).

DISCUSSION

MRI scans have been found to be increasingly accurate in the diagnosis of acute knee ligament tears. In addition, an MRI technique was recently reported to be accurate in the identification of posterolateral knee injuries.¹² Because it has been reported that the historical incidence of posterolateral knee injuries has been underestimated and under-reported, with a reported incidence of between 4% and 7%,^{1,5,16,17,26} it was believed that a large prospective MRI study would provide, as closely as possible, the actual number of posterolateral knee injuries that occur in the general population. In this study, we found an overall incidence of high-grade posterolateral knee injuries of 9.1% in patients with an acute knee injury with a hemarthrosis.

In assessing the subset of knees with acute knee ligament injuries, PLC injuries were found to be more common than PCL tears (16% v 10%). ACL tears were the most common ligament injury and were present in 74% of patients with acute ligament tears, with 39% of these occurring in the setting of multiple ligament injury. An overwhelming majority of posterolateral knee injuries occurred as part of a multiple ligament injury profile (87%), with an associated ACL tear being the most common. Isolated posterolateral tears were uncommon and occurred in 13% of the overall posterolateral knee injuries.

Although this study provides valuable insight into the incidence of posterolateral and multiple ligament injuries, we realize that there are limitations to this analysis. First, only patients presenting to an MRI referral center were included in the study. It is not known what percentage of patients with acutely injured knees with a hemarthrosis underwent imaging at this MRI center, nor is it known whether a higher percentage of patients with more severely injured knees were referred to these particular sites. Overall, this MRI center covers most of our metropolitan area with its 6 sites and is recognized as the major referral center for MRI scans. Second, it is not known whether some of these patients may have had previously undiagnosed knee injuries. We did, however, only include patients who had self-reported first-time knee injuries, in which an effusion developed within 24 hours, and who had no prior history of ipsilateral knee surgery. In addition, all patients were noted to have edema in the region of their injuries on the T2-weighted sequences on the MRI scans, which would greatly increase the likelihood that these were acute ligament tears. Third, it is difficult to estimate the number of patients with acutely injured knees who were treated outside of the formal medical care system or who may have been referred to smaller MRI centers. In addition, patients with more severely injured knees with a hemarthrosis may have been evaluated at emergency departments and trauma centers and had MRI scans obtained at these locations. It is also recognized that only the patients with more severely injured acute knee injuries who presented to outpatient offices may have been referred for MRI scans. However, in our community it is common practice to obtain an MRI scan in almost all patients who present with a knee hemarthrosis. Finally, although we believe that an examination under anesthesia is the "gold standard" for the evaluation of acute knee ligament injuries, it is possible that the radiologists' evaluation of these injuries may overestimate, or underestimate,

the incidence of clinically significant posterolateral knee injuries. In this regard, we only evaluated acute knee injuries with a hemarthrosis in this study and required the presence of soft-tissue edema or evidence of a complete loss of continuity of a structure to be defined as a high-grade structure tear. The accuracy of this posterolateral knee MRI technique has been previously reported to be 95% for the FCL, 90% for the PLT, and 68% for the PFL for diagnosing complete tears of these structures.¹²

There is a paucity of published studies evaluating the incidence and breakdown of the major ligament injuries of the knee. Two of these studies evaluated the incidence of acute ligament injuries arthroscopically in patients with a hemarthrosis, and both found the incidence of ACL tears (acute and partial) to be 72%.^{1,5} Although this incidence has been the accepted standard for the incidence of ACL tears with acute knee effusions, we believe that it is higher than the actual incidence of ACL tears seen in patients with acute knee effusions. In both of these studies, the higher percentage of ACL tears identified compared with our study may be a result of the different diagnostic and clinical criteria that have developed over the past 2 decades.^{1,5} Because both of the previous studies were performed before the use of MRI, the patients underwent diagnostic arthroscopy to help identify their pathology. In addition, MRI may be overly sensitive when a physical examination is not taken into account.

Noyes et al.⁵ arthroscopically evaluated 85 acutely injured knees with a hemarthrosis. They found that 72% of patients had an ACL injury. This is higher than our finding of a 41.1% incidence of ACL tears in patients with acute knee effusions. DeHaven¹ also completed an arthroscopic study of 113 cases with acute knee injuries with a hemarthrosis. He also found a higher percentage of ACL tears (72%) than our finding.

In 1986, 2,923 patients with knee injuries were identified who presented to 2 emergency departments in Aarhus, Denmark, over an 18-month period.²⁶ However, the authors did not limit their study to patients with an acute traumatic effusion. Of the patients with ligament-injured knees in their study, 76 had ACL tears (48 isolated and 14 involving multiple ligaments), which represented approximately 26% of their ligament-injured patients. Only 5 cases were diagnosed as FCL injuries, and only 5 PCL injuries were diagnosed.

In San Diego, California, the Kaiser Health Group found that from mid 1985 to mid 1988, 1,833 patients

sustained an acute knee injury, with 500 of these (27.3%) sustaining a knee ligament tear.²⁷ Of the patients with acute ligament tears, 47.6% had isolated ACL tears and 12.8% had combined ACL and MCL tears. Isolated MCL tears were the next most common ligament injury, accounting for 28.8% of injuries. Isolated and combined PCL tears were noted in 3.6% and 3.8%, respectively, with isolated and combined lateral (fibular) collateral ligament injuries in 2% and 1.4%, respectively. The overall percentage of ACL tears for their patients with acute knee ligament injuries, 60.4%, was lower than our incidence of 74%. Their overall incidence of MCL tears was 41.6%, which was similar to our finding of an incidence of 39%. Overall, acute PCL tears constituted 7.4% of their acute knee ligament injuries, as compared with our incidence of 14.4% for acute PCL tears. They also found that 3.4% of patients with acute knee injuries had lateral (fibular) collateral ligament tears, as compared with our incidence of 9.6% for patients with an FCL tear.

In another study of 71 patients with posterolateral injuries, 72% of the posterolateral knee injuries were found in the setting of a multiple ligament injury.⁴ This is in contrast to our finding of 87% of posterolateral knee injuries occurring as a combined multiple ligament injury in this study. The difference between the former study and our study was that the previous patients had already been preselected and referred to a major referral center for these injuries. However, these 2 studies do confirm that most posterolateral knee injuries occur as combined concurrent knee ligament injuries rather than in isolation.

Isolated posterolateral knee injuries were found to be uncommon in this study, and we found that the majority (87%) of posterolateral knee structure tears occurred in conjunction with cruciate ligament tears. Thus it is important to recognize the possibility of a concurrent PLC knee injury in the face of a cruciate ligament injury so that the posterolateral knee injury is properly diagnosed and recognized, especially because it appears that high-grade PLC injuries rarely heal.^{11,28}

CONCLUSIONS

This study showed that in this population, the incidence of posterolateral knee injuries in patients with acute knee ligament injuries with a hemarthrosis was 9.1%. It also verified that most PCL and PLC injuries occur in combination with other ligament injuries.

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