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MR imaging of tibial collateral ligament injury: comparison with clinical examination

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Abstract. We sought to clarify the capability of routine magnetic resonance (MR) imaging of the knee to detect and grade tibial collateral ligament (TCL) injury. We also wanted to define the exact MR findings that were the most important for diagnosis. Sixty-three patients were clinically evaluated for TCL injury prior to MR imaging of the knee on a 1.5-tesla system. MR studies were scored with respect to multiple direct and indirect findings. By discriminant analysis, the overall accuracy of classification (into clinical grades 1, 2, 3 and normal) on the basis of MR was 65%. Accuracy for detection of abnormal TCLs was 87%. The most useful MR findings for detection and grading of TCL injury were direct signs: subcutaneous edema over the TCL, focal disruption of the TCL, increased signal in the TCL on T2-weighted images, and longitudinal striations within the TCL. Indirect signs such as trabecular trauma were less useful for TCL evaluation. The presence of a tear of the anterior cruciate ligament, however, correlated with TCL injury of a higher grade. T2-weighted coronal images, by better depicting intraligamentous edema and fiber disruption, improved the MR assessment of the TCL.

Key words: Tibial collateral ligament – Medial collateral ligament – Knee injury – Ligaments – MR imaging

Magnetic resonance (MR) imaging of the knee is an established method for identifying cruciate ligament injuries with a high degree of accuracy [1, 2]. However, objective information on the assessment of other ligamentous structures, including the tibial collateral ligament (TCL) of the knee, is lacking.

The TCL consists of superficial and deep portions; each has its functional significance. The superficial TCL courses from the medial epicondyle of the femur to the medial aspect of the proximal tibial metadiaphysis, where it inserts deep to the pes anserinus 7.5–10 cm below the joint line. A portion of the ligament takes an oblique course from the femoral epicondyle, coursing posteriorly to blend with the deep joint capsule (deep TCL), forming what is also called the posteromedial capsule or posterior oblique ligament [3, 4]. The superficial TCL is the primary support resisting valgus angulation and internal rotation of the tibia [5].

The deep portion of the TCL represents an area of thickening of the joint capsule separate from the superficial TCL anteriorly, but blending with the oblique portion of the superficial TCL in the posteromedial corner of the knee. The deep TCL spans a much shorter distance from the distal medial epicondyle to the proximal tibia, and has a fibrous attachment to the medial meniscus [3]. The deep TCL resists internal rotation and valgus stress with the knee in extension. In addition, the deep TCL resists anterior displacement of the tibia in the ACL-deficient knee [6, 7].

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Table 1. Criteria of evaluation of magnetic resonance imaging of the tibial collateral ligament: coding of variables[a]

1. Joint effusion (Effusion): 0=absent, 1=present
2. ACL tear (ACL): 0=absent, 1=present
3. Trabecular trauma: 0=absent, 1=present
4. Medial meniscal tear: 0=absent, 1=present
5. Discontinuity or focal nonvisualization of the TCL (Discontinuity): 0=absent, 1=present
6. Global thickening in the region of the TCL (Thickening): 0=less than 7 mm, 1=greater than or equal to 7 mm
7. Capsular thickening deep to superficial TCL (Capsular thickening): 0=absent, 1=present
8. Edema in subcutaneous fat adjacent to TCL (SQ): 0=absent, 1=present
9. Increased signal relative to fat in/deep to TCL on T2-weighted images (T2 Hyperintensity): 0=absent, 1=present
10. Longitudinal increased signal striations in TCL (Striated): 0=absent, 1=present
11. Medial compartment spurring (OA): 0=absent, 1=present

[a] Abbreviated names of variables are given in parentheses

Clinical grading of TCL injury is determined by examination for valgus laxity in extension and in 30° of knee flexion [8]. The clinical grade of injury influences the choice of therapy [9, 10]. Investigators have documented that tears of the TCL can be identified at MR imaging [11]. However, there is no established method to estimate the severity of injury on the basis of the MR findings. This study attempts to define the most useful MR criteria for identifying and distinguishing between grades of TCL injury.

Methods

MR examinations of 41 patients with TCL injury and 22 patients with clinically normal TCLs were retrospectively reviewed by an experienced musculoskeletal radiologist without knowledge of the clinical findings. MR examinations were performed on a 1.5-tesla imager (General Electric, Signa, Milwaukee, Wis.) using a transmit-receive extremity coil. An axial T1-weighted spin echo sequence was obtained using 5-mm sections and a 2.5-mm interval (matrix 128 × 256). Sagittal (matrix 192 × 256) and coronal (matrix 256 × 256) proton-density and T2-weighted spin echo images were obtained using a 3-mm section and 1.5 mm interval. Clinical evaluation of the patients was performed by the orthopedic staff, based on the grading system established by Hughston [8].

The MR criteria that were examined, the manner in which they were coded, and their abbreviated names are shown in Table 1. The major MR criteria are illustrated in the accompanying figures. The normal superficial TCL (Fig. 1) is typically visualized on three sequential coronal MR images (3-mm sections, 1.5 mm gap). The deep portion of the TCL is not distinctly identified on routine MR images. Fat is usually interposed between the superficial TCL and the deep capsule and meniscal base on more anterior images through the ligament (Fig. 1). The MR findings in ACL rupture (criterion 2), trabecular trauma (criterion 3), and meniscal tear (criterion 4) have been well described in the literature [1, 2, 12]. Discontinuity (criterion 5) was defined as focal absence or more diffuse non-visualization of normal low signal ligamentous fibers (Fig. 2). Global thickening in the region of the TCL ("Thickening," criterion 6) was determined by measuring the maximal transverse dimension from the surface of the TCL to the cortex of the nonarticular portion of the adjacent femur or tibia (Fig. 3). Values above 7 mm were considered abnormal. Capsular

Fig. 1. Normal tibial collateral ligament (TCL): The superficial TCL (*black arrows*) courses from the medial epicondyle of the femur to the medial proximal tibial shaft, and is seen as a thin, linear hypointense structure. The deep TCL cannot be separately identified on routine magnetic resonance (MR) images. Note normal pericapsular fat deep to the TCL (*white arrow*) TR 1500, TE 12

Fig. 2. Discontinuity, T2 Hyperintensity: Individual with clinical grade 3 TCL injury exhibits focal discontinuity of the TCL over the medial epicondyle (*white arrows*), as well as hyperintense signal within the TCL substance (*black arrow*) TR 1500, TE 70

Fig. 3. Thickening, Trabecular trauma: There is an increase in the thickness (*white arrowheads*) of the TCL substance (which in this case also exhibits a diffuse increase in signal intensity) in this individual with a grade 3 TCL injury. Thicknesses greater than 7 mm in width were considered abnormal. Trabecular trauma in the lateral tibial plateau is also illustrated (*small black arrows*). Note sartorius fascia (*black arrow*) superficial to the TCL. TR 1500, TE 12

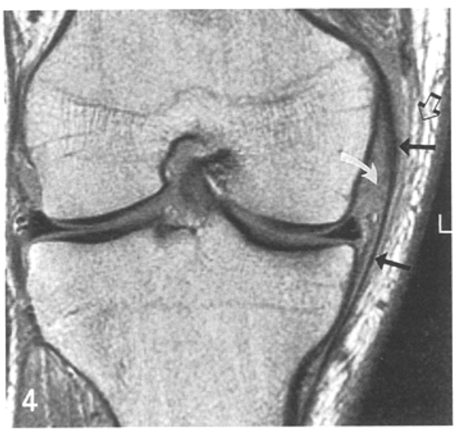

Fig. 4. Capsular thickening, subcutaneous edema: This individual with clinical grade 1 TCL injury demonstrates intermediate-intensity signal material (*curved arrow*) in the area of the deep capsule, beneath the superficial TCL (*straight arrows*). Edema is seen as streaky low signal in the overlying subcutaneous fat (*open arrow*). TR 1500, TE 19

Fig. 5. Striated TCL: Individual with clinical grade 1 TCL injury shows longitudinal increased signal (*arrows*) within a thickened TCL, creating a striated appearance. TR 1500, TE 12

thickening (criterion 7) was interpreted as the presence of nonfatty tissue deep to the low-signal fibers of the superficial TCL (Fig. 4). Subcutaneous edema over the TCL ("SQ," criterion 8) is illustrated in Fig. 2. T2 Hyper-intensity (criterion 9) was defined as signal greater than or equal to that of fat within TCL on T2-weighted images (Fig. 2). Longitudinal increased signal striations in the TCL ("Striated," criterion 10) is illustrated in Fig. 5. The presence of medial compartment spurring or osteoarthritis (OA, criterion 11) was scored, because osteophytes can account for apparent capsular thickening (criterion 7).

The distribution of MR criteria (discriminating variables) across clinical groups was analyzed using an *F*-test. Discriminant analysis [13] was performed to define the collective ability of the MR criteria to correctly classify cases with respect to the clinical status of the TCL. Discriminant analysis is a multivariate statistical technique in which classification of cases into groups is optimized. Determination of the relative discriminating power of individual MR criteria was performed using a Wilks' stepwise variable selection method. The minimum p value to enter and the maximum p value to remove a variable in the stepwise selection process were 0.25 and 0.30, respectively. Discriminant analysis was implemented using the Statistical Package for Social Sciences (SPSS Inc., Chicago, Ill.).

Variables with the highest F values in the one-way analysis will not necessarily have the greatest discriminating power, because the one-way analysis does not account for the interactions between variables. Values for accuracy of classification are the number of correctly classified subjects divided by the total number of subjects.

Results

MR examinations of a total of 63 knees were analyzed. Of these 63 knees, 22 had clinically normal TCLs, 13 had grade 1 injuries, 18 had grade 2 injuries, and 10 had grade 3 injuries. The average patient age was 31 years (range 16–85 years). At the time of MR examination, the median interval since injury was 10 days (range 1–72 days).

All clinical groups

One-way analysis of variance (F test) of the distribution across clinical groups for MR criteria shows the highest significance for the variables T2 Hyper-intensity, Discontinuity, SQ, Thickening, and Trabecular trauma ($p<0.01$). No significance exists for the variables Effusion, OA, Medial meniscal tear, Capsular thickening, and Striated ($p>0.10$).

Discriminant analysis yields an overall accuracy of classification of 65% (Table 2). In the stepwise variable selection, the variables with the greatest discriminating power are (in descending order) SQ, Discontinuity, T2 Hyperintensity, and Striated. All of these variables are positively correlated with the first canonical discriminant function (T2 Hyperintensity and Discontinuity having the highest correlation), in which higher scores correspond to greater severity of injury. SQ and Striated have the highest correlation with the second canonical discriminant function, which tends to separate grade 2 from grade 1 and grade 3 injuries. The variables Medial meniscal tear, Thickening, Trabecular trauma, and Capsular thickening are not selected.

Table 2. Classification results by discriminant analysis (all groups)

Actual group	No. of cases	MR-predicted group			
		Normal	1	2	3
Normal	22	18	0	3	1
Grade 1	13	1	7	3	2
Grade 2	18	2	1	9	6
Grade 3	10	0	0	3	7

Normal versus abnormal TCLs

One-way analysis of variance (F test) of the distribution between normal and abnormal clinical groups shows the highest significance for (in descending order) T2 Hyperintensity, Thickening, Discontinuity, and SQ ($p<0.01$). No significance exists for the variables Capsular thickening, Effusion, ACL, and Striated ($p>0.10$).

Discriminant analysis yields an accuracy of classification of 87%. In the stepwise variable selection, the variables with the greatest discriminating power are (in descending order) T2 Hyperintensity, Striated, Discontinuity, and SQ. As expected, all of these variables are positively correlated with an abnormal TCL. The variables Trabecular trauma and Medial meniscal tear are not selected.

Grade 1 versus grades 2 and 3 TCL injury

One-way analysis of variance (F test) of the distribution between grade 1 and higher grades of TCL injury shows significance only for the variable ACL ($p<0.05$). Discriminant analysis yields an accuracy of classification of 68%. In the stepwise variable selection, ACL is the only variable selected, correlating with the presence of a higher grade (grades 2 and 3) of injury.

Discussion

Our results support the prevailing impression that MR is capable of detecting TCL injury (87% correct classification). The false-positive rate for MR (18%) was greater than the false negative rate (6%). It is certainly plausible that MR is actually more sensitive for minor ligamentous injury than the clinical examination. If this is so, the "true" accuracy figure for MR could be higher.

The agreement between MR and the clinical grade of injury was more modest (65% correct classification). The highest rate of misclassification was for grade 2 injuries (50%), which is not suprising given the considerable heterogeneity of this clinical group.

For detecting and grading TCL injury, the most important MR criteria proved to be SQ, Discontinuity, T2 Hyperintensity, and Striated. Generalized thickening (Thickening) in the region of the TCL is of diagnostic value, but offers no additional information compared to the other signs. A "striated" appearance of the TCL may be a relative indicator of grade 2 as opposed to grade 1 or 3 injury. The presence of an ACL tear, while not particularly useful for detecting TCL injury, tends to indicate a more severe (grade 2 or 3) TCL injury.

We initially thought that capsular thickening might be a helpful indicator of low-grade TCL injury if the deep capsule (or deep TCL) ruptures before the thicker and stronger superficial TCL. This hierarchy of lesions may occur in injuries sustained with the knee in 90° of flexion [14]. However, our analysis does not support the value of the MR finding of thickening (due to hemorrhage or edema) in the area of the deep capsule as a sign of low-grade TCL injury.

Coronal T2-weighted images appear to be important for an accurate MR assessment of the TCL. T2-weighted images and the proton density images acquired with them have been, in our experience, superior to T1-weighted images for the detection of focal discontinuity in the TCL. Furthermore, our analysis shows that the finding of hyperintensity in or around the TCL on T2-weighted images is valuable for both the detection and grading of TCL injuries. This finding presumably represents intraligamentous hemorrhage or edema, or, in a small number or cases, synovial fluid leakage through the deep capsule. The TCL bursa can occasionally appear as a well-defined, fluid signal area deep to the superficial TCL, adjacent to the base of the mid-zone medial meniscus [15]. Fluid distention of the TCL bursa can indicate a TCL bursitis, but this finding should not be confused with the more irregular and ill-defined high-signal changes in the same area seen in TCL injury.

The lack of a gold standard in the assessment of the TCL necessitated the use of the imperfect standard of the physical examination in this study. It is likely that the true diagnostic value of MR in the evaluation of the TCL is greater than our analysis suggests. Nevertheless, the clinical evaluation does provide a yardstick by which to measure the "relative" value of various MR signs in grading TCL injury. By pooling lesions of various ages, our analysis may distort the relative significance of variables which evolve more rapidly over time, such as SQ and T2 Hyperintensity.

In conclusion, the MR findings most useful in evaluating the TCL are those directly related to the anatomic area of the TCL (hyperintensity in or around the TCL on T2-weighted images, discontinuity or nonvisualization of low-signal ligamentous fibers, edema in the subcutaneous fat over the TCL, longitudinal increased signal striations in the TCL substance). The more of these direct MR signs that are positive in a particular case, the greater is the likelihood of a higher grade of injury. T2-weighted coronal images seem to be important for optimal detection and grading of TCL injury by highlighting ligament fiber interruption and intraligamentous edema. Long TE fast spin-echo images may prove to be equally effective for this purpose. Most indirect findings such as trabecular trauma, a useful secondary sign of ACL tear [16], were not helpful in assessing the TCL. The presence of an ACL tear, however, does correlate with TCL injury of a higher grade (grades 2 and 3).

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