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Abstract

Purpose: The role of MR imaging in grading medial collateral ligament (MCL) injury of the knee in comparison to other grading methods (clinical findings and instrumental measurement) is hardly documented in the literature. The purpose of this study is to compare the results of MR imaging in grading acute MCL injuries to the results of a clinical grading by an instrumented valgus-varus laxity tester (WLT).

Materials and methods: Twenty-one patients clinically suspected of acute MCL injury were tested by VVLT, a well documented and instrumented test-device. All patients subsequently underwent MR imaging of the knee. MCL injury was graded independently by VVLT and MR imaging using a classification method with reference to Petermann. Results: Nineteen patients had corresponding grading results by VVLT and MR imaging (kappa, 0.83; S.E., 0.10); 14 patients had a Grade I, four a Grade II and two patients had a Grade III MR imaged MCL injury. Associated lesions were also depicted on MR imaging (bone contusion (n = 3), ACL disruption (n = 2) and medial meniscal rupture (n = 1)). Conclusions: This study shows a very high degree of agreement between the results in grading acute MCL injuries with MR imaging and an instrumented valgus-varus laxity tester (VVLT). MR imaging depicted important, clinically undetected, additional lesions which can determine the treatment of MCL injury.

Keywords: Knee, MRI; Knee, injuries; Knee, ligaments and menisci; Trauma, knee

1. Introduction

Nowadays MR imaging is an acknowledged diagnostic tool for evaluating internal derangements of the knee such as meniscal tears and cruciate or collateral ligament injuries. Grading of medial collateral ligament (MCL) injury with MR imaging is hardly documented in the literature [1–5], probably because surgical exploration is the only gold standard; MCL will only be explored surgically when there is gross medial instability and repair is anticipated.

In our hospital a study was performed to compare the functional outcome of patients with grades I–III MCL lesions with limited motion brace treatment or functional treatment alone. MCL injury was graded independently by clinical assessment, valgus-varus laxity tester (VVLT) and MR imaging. As a part of the study mentioned above, we tested the hypothesis that MR imaging is able to grade MCL injuries comparable with clinical grading and instrumental measurement. The purpose of this report is to compare the results of MR imaging with a VVLT in grading MCL injury.
Fat-suppressed T2-weighted imaging was performed to evaluate the presence of any fluid or contrast uptake in the infrapatellar fat pad, which can indicate an associated injury. The images were reviewed for any abnormalities, and the findings were correlated with the patient's clinical symptoms and history.

### Table 1: Comparison of MR Imaging of MCL Injury with the Grading System

<table>
<thead>
<tr>
<th>Grade</th>
<th>MR Imaging</th>
<th>VALLT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No evidence of MCL injury</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>Partial tear of MCL</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Complete tear of MCL</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Partial tear of other ligaments</td>
<td>3</td>
</tr>
</tbody>
</table>

**Note:** VALLT = Visual and Anatomical Lamina of the Ligament Tension Test

2. **Methods and Results**

In the presence of instability, an L-R KT-1000 examination was performed to assess the laxity of the knee. The results were compared with the patient's clinical symptoms and previous radiographic findings.

### Table 2: Grading System for Assessment of Knee Instability

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Normal laxity</td>
</tr>
<tr>
<td>1</td>
<td>mild laxity</td>
</tr>
<tr>
<td>2</td>
<td>moderate laxity</td>
</tr>
<tr>
<td>3</td>
<td>severe laxity</td>
</tr>
</tbody>
</table>

**Note:** L-R KT-1000 = Lateral-Quadriceps Tension Test

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valgus-varus laxity of the knee by a three-space Isotrak system, based on the measurement technique described by other authors [7–9]. The relative valgus and varus rotation with a load of 10 Nm and 20 Nm, expressed in degrees, are the parameters for expressing the valgus and varus laxity. The laxity of the anterior cruciate ligament (ACL), as tested by an instrumented AP-tester [10] in the same session, should be within the normal range.

Subsequently all patients underwent MR imaging of the knee on a 1.5-T system (63/84 Sp Magnetom, Siemens). The examination was performed with the patient in a supine position with the knee in slight hyperextension and placed in a surface knee coil. The standard protocol consisted of T1- (TR (ms)/echo time (ms): 700/15) and T2- (Flash 2D, gradient echo sequence 800/18, $15^\circ$ flip angle) weighted coronal images (section thickness 3 mm, field of view 180 mm, gap 0.2, matrix 256 x 256) and sagittal T1-weighted images (with the same MR parameters). Oblique sagittal ($10^\circ$–$20^\circ$ of internal rotation) and double angulated coronal Flash 2D images oriented to the ACL axis were made to supple-

Fig. 2. Grade II MCL injury. (a) Coronal T1-weighted MR image (700/15) shows intermediate signal across the total width of the superficial layer (small arrowhead). (b) Coronal Flash 2D MR image (800/18, $15^\circ$ flip angle) shows longitudinal increased signal striations across the total width of the superficial layer (small arrowhead), corresponding with total disruption of the femoral part of the superficial layer of MCL. This layer is markedly displaced from the bone because of periligamentous swelling (see also a, arrowheads). Joint effusion (asterisk). The deep layer (not disrupted) is not depicted on this coronal image.

ment this routine protocol. The radiologist evaluated the images without knowledge of the results of the clinical assessment and VVLT in grading MCL injury.

We used the classification method shown in Table 1 [11] to grade MCL injury by VVLT and MR imaging. The MCL complex includes a superficial layer and a deep layer. To grade MCL injury by MR imaging we look at periligamentous swelling, disruption of the superficial and/or deep layer. Periligamentous swelling on MR imaging corresponds with intermediate signal on T1- and high signal on T2-weighted (Flash 2D) coronal images from increased soft tissue between the superficial layer of MCL and the subcutaneous tissue or the medial femoral condyle/tibia plateau. Complete disruption of the superficial layer is seen as an intermediate signal on T1- and high signal on T2-weighted coronal images across the entire width of this layer. Disruption of the superficial layer is properly evaluated on two or three successive coronal images. Fluid (intermediate signal on T1- and high signal on T2-weighted images) extravasating from the knee joint through the
meniscotibial or meniscofemoral ligament (deep layer) into the periligamentous tissue (between the superficial layer and femoral condyle/tibia plateau) corresponds with complete disruption of the deep layer on MR imaging.

Besides the MCL other structures well examined are the cruciate ligaments, the menisci and bone. Additional abnormal findings of the knee were also noted.

3. Results

MCL injuries in 21 patients were graded by VVLT and MR imaging; 19 male and two female patients ranged in age from 17 to 50 years (mean, 28 years).

Comparison of the findings at MR imaging and the results of VVLT is summarized in Table 2: a good agreement between the results of grading MCL injuries with MR imaging and VVLT using a classification method was found (kappa, 0.83; S.E., 0.10) [12].

From the 14 patients with periligamentous swelling on MR imaging (Grade I MR imaged MCL injury) 13 were graded as Grade I lesion by VVLT; nine also showed thickening of the superficial layer of MCL at the same place as periligamentous swelling and two patients also showed focally increased signal intensity of the superficial layer without complete disruption of the superficial layer (Fig. 1). One patient with Grade I MR imaged MCL injury was graded as a Grade II MCL injury by VVLT: there was a 7-week time-delay between trauma and MR imaging.

All five patients with Grade II MR imaged MCL injuries were also graded as a Grade II lesion by VVLT (Fig. 2).

Of two Grade III MR imaged MCL injuries one patient was also graded as a Grade III lesion by VVLT; this patient did not show associated lesions on MR imaging (Fig. 3). The other patient with ACL rupture as well as bone contusion of the lateral compartment (lat-
is a local condensation of the medial capsule which is
located more distal to the knee joint. The deep layer (medial capsular ligament)
and its interposed between the superficial layer and
the deep layer of the MCL. The deep layer is a dense, fibrous, and
innervated layer that provides stability and control to the knee joint. The
superficial layer is composed of a fibrous capsule and a deep layer (12,13). The superficial
layer of the MCL is a superficial and a deep layer (12,13). The superficial
layer of the MCL is a superficial and a deep layer (12,13).

4. Discussion

The MCL is a capsuloligamentous complex consisting of the knee joint and the
medial femoral condyle. It plays a crucial role in stabilizing the knee joint and
preventing anterior and lateral subluxation of the femur on the tibia. The
MCL is the primary restraint against excessive valgus stress, and its integrity
is critical for maintaining joint stability. Damage to the MCL can lead to
instability and decreased function, necessitating surgical intervention to
restore normal function and prevent chronic knee pain. The diagnosis of MCL
injury is often made on MRI, where abnormal signal intensity and abnormal
appearance of the MCL fibers can be observed. Treatment options include
nonoperative management and surgical repair, depending on the severity of
the injury and the patient's activity level.
eral femoral condyle and tibia plateau) of the knee as seen on MR imaging was graded as a Grade II MCL injury by VVLT. MR imaging also depicted associated lesions in the MCL injured knees: popliteal cyst (n = 1), medial meniscal rupture (n = 1), bone contusion (n = 3, lateral compartment) and ACL rupture (n = 2).

4. Discussion

The MCL is a capsuloligamentous complex consisting of a superficial and a deep layer [13,14]: the superficial layer of the MCL complex, a primary restraint against valgus stress, arises from the medial femoral condyle and inserts on the tibia metaphysis just deep to the pes anserinus tendons. The superficial layer, approximately 1.5 cm wide, is visualized as a thin dark stripe on all spin-echo images, paralleling and often inseparable from the dark cortices of the medial femur and tibia (Fig. 4). Most of the superficial layer fibers are oriented in a slightly superoposterior to inferoanterior direction. It is important to evaluate the MCL properly on MR imaging in this direction on two or three successive coronal images. The deep layer (medial capsular ligament) is a focal condensation of the medial capsule which is firmly adherent to the medial meniscus. The proximal and distal parts relative to the meniscus are the meniscofemoral and meniscotibial ligaments (Fig. 4). Garvin et al. [2], who evaluated surgically proven MCL injuries retrospectively with MR imaging, did not grade the MCL injury (partial or complete tear) with reference to the anatomy of the MCL complex (superficial and deep layer). An underestimation of the severity of MCL injury by MR imaging was noted, probably because no T2-weighted coronal images of the knee were performed, in contrast to our study. Proton density/T2-weighted (especially with fat-saturated T2-weighted) images can improve visualization of collateral ligaments and of the related injuries on MR imaging [4,5,15]. Several studies found a moderate accuracy of MR imaging in grading MCL injury of the knee in comparison to clinical examination, which is an imperfect standard. In contrast to these studies, we compared MCL injury on MR imaging with a grading system based on laxity tests with a documented instrumented test-device (VVLT).

A rupture of the deep layer is always accompanied by a rupture of the superficial layer [11]. Because the deep layer is not always depicted by our MR imaging protocol of the knee, fluid extravasating from knee joint into
the periligamentous tissue is used as an indirect sign of complete disruption of the deep layer. This sign is well evaluated on a T2-weighted image in addition to the T1-weighted coronal image. Further research with a larger number of patients with MCL injury should be done to confirm the hypothesis that extravasation of joint fluid into periligamentous tissue is a reliable sign corresponding with a Grade III MCL injury on MR imaging.

This study shows a very high degree of agreement between the results of MR imaging and VVLT in grading MCL injury. In one patient with a Grade II VVLT tested MCL injury MR imaging underestimated the MCL injury, probably as a result of a reasonable time-delay of 7 weeks between the trauma and MR imaging corresponding with a moment after the initial stage (hematoma formation and infiltration of inflammatory cells) of ligament repair [13]. All the other patients were examined in the first 2 weeks after trauma. Another patient with a Grade III MR imaged MCL injury was undergraded by VVLT, probably due to an intact ACL which served as a secondary valgus stress restraint.

Normally clinical examination alone is an imperfect standard of grading ligament injury (as a result of inter- and intraobserver variability, posttraumatic pain and swelling). The VVLT gives objective, quantitative information of valgus-varus laxity of the knee joint as a measure of knee stability in this direction [16]. Research of validity (maximum systematic error: 0.375) and reproducibility (C.V. at 20 Nm valgus-varus: 6%) of VVLT showed good results [6].

The treatment of an isolated MCL injury is generally conservative. Surgical treatment is considered if other structures are involved (menisci, ACL) or sometimes in the case of a Grade III MCL injury. MR imaging is able to depict detailed knee joint anatomy, with associated lesions such as ACL rupture and/or medial meniscal tear in (especially high grade) MCL injured knees [13]. Two patients without clinical anteriorposterior instability (tested by AP-tester and Lachman test) showed ACL disruption on MR imaging which was confirmed by arthroscopy several weeks posttraumatically. Directly after the trauma muscle tension can have quite an influence on the results of manual (Lachman test) or instrumented (AP-tester) testing for laxity of the ACL [17]. One patient with a medial meniscal tear, as depicted on MR imaging, subsequently underwent an arthroscopy and partial meniscectomy.

High-grade MCL injuries are commonly accompanied by bone contusions or bruises [14]; poorly defined subchondral areas of decreased signal intensity on T1W1 and increased signal intensity on T2W2 images in the lateral femur condyle and/or lateral tibia plateau. They represent trabecular microfractures, secondary to compressive forces acting on the contralateral side to the distracted medial compartment where the MCL injury is present [18,19]. We found bone contusion in two Grade I and one Grade III MCL injured knees; the bone contusions in these Grade I MCL injured knees are probably related to the direct compressive forces within the lateral compartment of the knee. The long-term sequelae of these bone bruises are not yet known.

In conclusion this study shows a high degree of agreement between the grading results of acute MCL injuries as evaluated by MR imaging with a clear practical classification method and the VVLT as a well documented, instrumented test-device. The MCL injury has been properly evaluated and classified by MR imaging with good understanding of the anatomy of the MCL complex. We see MR imaging as a practical and competent tool in diagnosing acute severe ligament injuries of the knee in case of doubtful manual valgus stress test results and doubtful or absent instrumented laxity test results. MR imaging can depict associated lesions of the MCL injured knee which can mainly influence therapy.

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References


