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ACCURACY OF MAGNETIC RESONANCE IMAGE IN THE DIAGNOSIS OF MULTIPLE LIGAMENT KNEE INJURIES: A MULTICENTER STUDY ON 178 PATIENTS

Enrique Sanchez-Munoz, MD. *Corresponding author.
Knee Unit. Department of Traumatology and Orthopaedic Surgery. Toledo University Hospital. Avda. del Río Guadiana, 45007 Toledo, Spain.
Centro Clínico Quirúrgico, Aranjuez, Spain
Contact information: Department of Traumatology and Orthopaedic Surgery. Toledo University Hospital. Avda. del Río Guadiana. 45007. Toledo, Spain.
email: sanchezorthopaedic@gmail.com
instragram: @sancheztrauma

Beatriz Lozano Hernanz, MD.
Knee Unit. Department of Traumatology and Orthopaedic Surgery. Toledo University Hospital. Toledo, Spain.

Jacco A.C. Zijl, MD.
Department of Orthopaedic Surgery. St. Antonius Hospital, Utrecht, The Netherlands.

Nienke Wolterbeek, PhD.
Department of Orthopaedic Surgery. St. Antonius Hospital, Utrecht, The Netherlands.

Luís Eduardo Passarelli Tirico, MD, Assistant Professor.
Orthopedic and Traumatology Institute - Hospital das Clinicas - University of São Paulo Medical School, São Paulo, Brazil.

Fabio Janson Angelini, MD.
Orthopedic and Traumatology Institute - Hospital das Clinicas - University of São Paulo Medical School, São Paulo, Brazil.

Peter C. M. Verdonk, MD, PhD, Professor.
Antwerp Orthopaedic Centre Monica Hospitals, Antwerp, Belgium.
MoRe Foundation, Antwerp, Belgium.

Kristien Vuylsteke, PhD.
More Foundation. More Institute. Antwerp, Belgium.

Renato Andrade, BSc.

Clínica Espregueira - FIFA Medical Centre of Excellence, Porto, Portugal.

Dom Henrique Research Centre, Porto, Portugal.

Porto Biomechanics Laboratory (LABIOMEP), Faculty of Sports, University of Porto, Porto, Portugal.

João Espregueira-Mendes, MD, PhD.

ORCID 0000-0001-7429-4900

Clínica Espregueira - FIFA Medical Centre of Excellence, Porto, Portugal.

Dom Henrique Research Centre, Porto, Portugal.

School of Medicine, University of Minho, Braga, Portugal.

ICVS/3B's–PT Government Associate Laboratory, Braga/Guimarães, Portugal;.

3B's Research Group – Biomaterials, Biodegradables and Biomimetics, University of Minho, Headquarters of the European Institute of Excellence on Tissue Engineering and Regenerative Medicine, Barco, Guimarães, Portugal.

Cristina Valente, PhD.

Clínica Espregueira - FIFA Medical Centre of Excellence, Porto, Portugal.

Dom Henrique Research Centre, Porto, Portugal.

Francisco Figueroa, MD.
Clinica Alemana-Universidad del Desarrollo. Santiago, Chile.
Hospital Sotero del Rio, Santiago, Chile.

David Figueroa, MD.
Clinica Alemana-Universidad del Desarrollo. Santiago, Chile.

Antonio Maestro Fernández. MD, PhD, Associated Professor.
School of Medicine, University of Oviedo, Oviedo, Spain.
Begoña Hospital, Gijón, Spain.

Investigation performed at the Toledo University Hospital, Toledo, Spain.

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ABSTRACT

Background: Magnetic resonance imaging (MRI) has shown limited diagnostic accuracy (DA) for multiple ligament knee injuries (MLKI), especially for posterolateral corner (PLC) injuries.

Hypothesis: DA of MRI in MLKI will only be moderate for some knee structures. Patient-related factors and injury pattern could modify MRI DA.

Study design: Diagnostic study; Level of evidence, 3.

Methods: All patients with MLKI surgically treated from January 2014 to December 2020 in the centers participating in the study were reviewed. We recorded sex, age, mechanism of injury, time from injury to MRI scan and vascular and neurological associated lesions. Lesions to the anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), medial collateral ligament (MCL), fibular collateral ligament (FCL), popliteus tendon (PLT), popliteofibular ligament (PFL), iliotibial tract (ILTT), biceps tendon (BT), medial and lateral meniscus and articular cartilage from MRI reports and surgical records were also gathered. MRI sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), DA, diagnostic odds ratio (DOR), positive and negative likelihood ratio and intraclass correlation coefficient were calculated for each knee structure. With logistic regression, associations between demographic and injury characteristics and MRI accuracy were assessed.

Results: A total of 178 patients (127 men, mean age 33.1 years) were included. High-energy trauma was the most common mechanism of injury (50.6%), followed by sports trauma (38.8%) and low energy trauma (8.4%). The ACL was the structure with the best

DA, DOR and PPV (94%, 113.2 and 96.8%, respectively). PLC structures displayed the worst DA (PLT: 76%, FCL: 80%) and DOR (PLT: 9.9, FCL: 17, PFL: 17.5). MRI was more reliable detecting absence of meniscal and chondral lesions than identifying them. Logistic regression found that MRI DA was affected by Schenck classification, with higher grades of Schenck lowering DA for peripheral structures (ILTT, PLT and BT) and improving DA for ACL and PCL.

Conclusion: DA of MRI for MLKI largely varied among knee structures, with many of them at risk of misdiagnosis, especially PLC, meniscal and chondral lesions. Severity of MLKI lowered the DA of MRI for peripheral structures.

Key Terms: Knee ligaments, multiple ligament injuries, meniscus, imaging, magnetic resonance.

What is known about the subject: MRI is reported as not capable to reliably diagnose injuries to all the structures of the knee in patients with MLKI. Specially, the structures of the posterolateral corner of the knee are at risk of misdiagnosis. Most studies that had assessed MRI diagnostic accuracy to identify MLKI are case series with small sample size. There is a clear need for larger studies to increase the statistical power.

What this study adds to existing knowledge: This is the biggest study on diagnostic accuracy of MRI in MLKI to date, and the first one on this topic having a multicenter nature. It is the first one to identify, having statistical significance, factors that influence the DA of MRI in these lesions. DA of MRI for MLKI varies among knee structures, with many of them at risk of misdiagnosis, especially PLC, meniscal and chondral lesions. Severity of MLKI influences DA of MRI, with significantly worst diagnostic performance for peripheral structures (ILTT, PLT and BT) and improved DA for ACL and PCL. Orthopaedic surgeons should be aware of the potential risk of misdiagnosis when relying on MRI findings for surgical planning and that the more severe MLKI are associated with lower DA for peripheral knee structures.

INTRODUCTION

Multiple ligament knee injuries (MLKI) are a rare entity, with an incidence of 0.02% to 0.2% of all orthopaedic injuries,[18] but with a high rate of associated vascular (5% to 18.4%) and nerve (19.2% to 25%) injuries.[14,17,18,21] A better understanding of the diagnostic accuracy (DA) of magnetic resonance imaging (MRI) to identify MLKI will improve surgical planning, avoiding misdiagnosis and inadequate treatment, two of the main causes of failure when treating MLKI.[15,29] Since clinical diagnosis based on examination is usually difficult due to pain and swelling,[3,10,16] stress radiographs[1,9,13] and MRI studies are essential to establish an accurate diagnosis.[1,10,27]

MRI is considered the gold standard for the diagnosis of ligament, meniscal and chondral lesions of the knee,[7] but not many studies have investigated the accuracy of MRI identifying injury pattern in MLKI.[1,3,5,8,10,12,13,16,21,23,24,26,30] Initial studies found good accuracy of MRI assessing MLKI lesions.[5,16,23,26] Later studies with larger sample sizes, that systematically evaluated each structure of the knee on MRI and surgical reports, have however shown poorer correlation between MRI and operative findings.[1,3,8,12] Most studies that had assessed diagnostic accuracy of MRI to identify MLKI are case series with small sample size [5,8,10,12,16,23,25,26,30] or studies based on tertiary referral centers with only a single surgeon[13,21,22] or radiologist involved.[10,13,16] Thus, there is a lack of bigger multicenter studies of better quality, that will allow to reach statistically significant conclusions that could be used as a guide in clinical practice.

The main purpose of this study was to establish the diagnostic accuracy of radiologist´s MRI reports, when reported by experienced musculoeskeletal radiologists, assessing lesions of the knee structures in patients with MLKI. Secondary objective was to establish whether patient-related factors and injury pattern influence the DA of MRI in MLKI. The hypothesis was that MRI is a useful diagnosis tool for assessing lesions of knee ligaments, menisci and cartilage in MLKI, but DA for some specific structures will only be moderate. We also hypothesized that patient-related factors and injury pattern could modify MRI diagnostic accuracy.

METHODS

This was a multicenter observational diagnostic study involving seven centers from six countries (Belgium, Brazil, Chile, The Netherlands, Portugal and Spain). The study was conducted in conformity with the Helsinki Declaration and was approved by the Regional Ethics Committee of the coordinating center (5th December 2019/RN 460). Additional institutional review boards approval was obtained in the others participating centers when pertinent.

All patients with diagnosis of MLKI surgically treated from January 2014 to December 2020 in the participating centers were eligible for inclusion. MLKI were considered as those with injury of at least two of the four main ligaments of the knee:[28] anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), medial collateral ligament (MCL) and posterolateral corner (PLC). Posterolateral corner comprises the fibular collateral ligament (FCL), the popliteus tendon (PLT) and the popliteofibular ligament (PFL),[6] injuries that involved at least one of the these three structures were considered lesions to the PLC.

Inclusion criteria were as follows: (1) skeletally mature patient, (2) diagnosis of MLKI, (3) surgically treated by a knee surgeon with experience in MLKI, and (4) MRI report of the knee prior surgery, reported by an experienced musculoskeletal radiologist. Exclusion criteria comprised: (1) previous lesion of the knee, (2) previous surgery of the knee, (3) concomitant fractures of the knee (except for bone avulsions associated with ligament lesions, such as arcuate fracture), and (4) patients with incomplete data.

Data collection

Sex, age, mechanism of injury (high energy trauma, low energy trauma or sports lesions), time from injury to magnetic resonance image scan (days), vascular lesions and neurological lesions were recorded for all patients from prospectively collected data.

Detailed data on knee injuries was gathered from MRI reports and surgical records. Data of the injured knee structures was recorded- ACL, PCL, MCL, FCL, PLT, iliotibial tract (ILTT) and the biceps tendon (BT) - and classified as normal, partial tear, complete tear or avulsion. Tears of the medial and lateral meniscus (MM and LM) were classified as normal or tear, and in regards to the location of the tear (anterior horn, mid-third or posterior horn). Chondral lesions were graded according to the International Cartilage Research Society (ICRS) Score[4] and the location of the cartilage lesion (femur (CartF), tibia (CartT) or patellofemoral joint (CartPF)) was also collected.

Data from MRI scan reports and surgical records was extracted to standardized spreadsheets after patients were anonymized. Review of the surgical records and MRI findings were assigned to different investigators in each center, each of them blinded for the MRI or surgical records within the same patient. Reviewers were orthopaedic surgeons in all centers but three, in which they were medical doctors dedicated to orthopaedic research. MRI scan systems and sequences used in each center are detailed in the appendix.

Final diagnosis stated on surgical records was established by the treating surgeon during surgery, based on exploration under anesthesia in the operating room, including stress radiographs when needed, and operative findings.

Each participating center fulfilled a spreadsheet with the patient data, MRI and surgical data, which was then sent to the coordinating center. All data was pooled and reviewed by two authors, with patients with incomplete data being excluded before statistical analysis.

Statistical analysis

Sample size calculation, using an alpha of 0.05 and beta of 0.20, showed that 167 patients were needed to reach statistical significance.

Statistical analysis was carried out by independent statistician who did not collaborate in the study, neither in the design nor data collection. Agreement between the MRI and surgical findings was assessed using intraclass correlation coefficient (ICC). The sensitivity (SEN), specificity (SP), positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio (LR +), negative likelihood radio (LR -), diagnostic accuracy (DA) and diagnostic odds ratio (DOR) were calculated using contingency table. Diagnostic accuracy is useful to determine the proportion of correct results that the test reaches. Its main two drawbacks are that it does not discriminate sensitivity and specificity and that it is dependent on prevalence. DOR is useful as a single indicator of test performance, it is the ratio of the odds of positivity relative to the odds of positivity in the non-diseased and has the advantage that is not prevalence dependent. The value of the DOR ranges from 0 to infinity, values higher than 1 indicate better discriminatory test performance, the higher the better, a value of 1 means that the test does not discriminate and values lower than 1 point to improper test interpretation.[11]

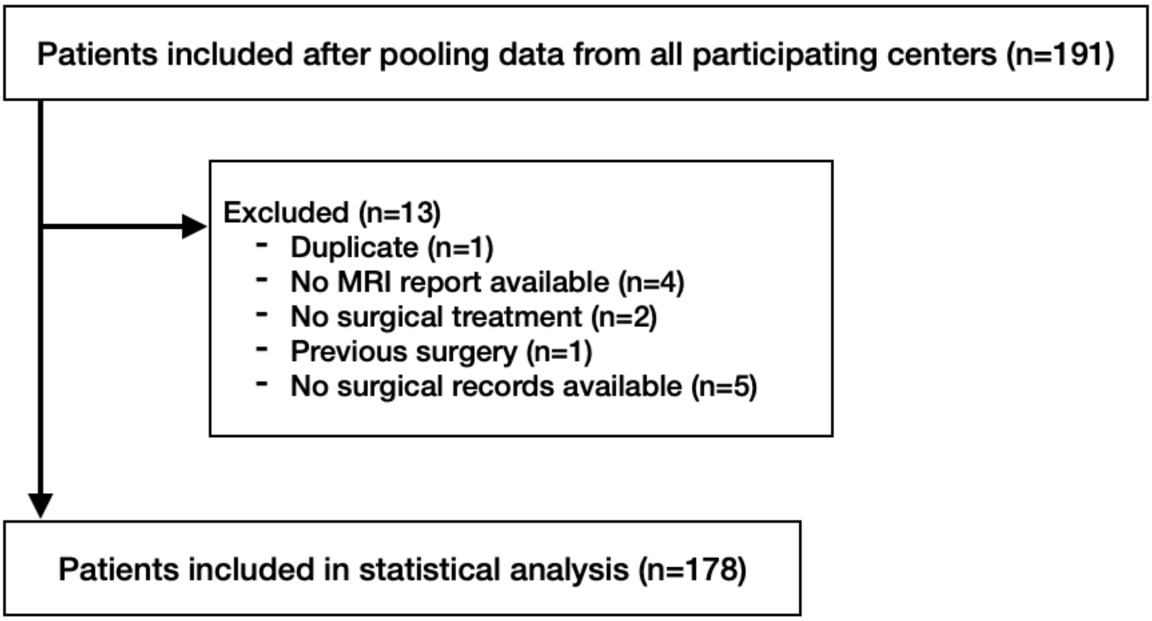
Descriptive data is defined either as mean and standard deviation (SD) or as frequency and percentage (%), as appropriate. Data was analyzed using contingency table. A new variable was defined to indicate whether there was success or failure between the reference and diagnostic variables. Once created, it was used as a dependent variable in a logistic regression and the factors (age, sex, mechanism of trauma, time to MRI scan, Schenck classification and Teslas of MRI scan) as independent variables. The regression was performed for each structure and when there were several variables with statistical significance, a multivariate approach was performed. The results from the regression are presented as odds ratios (OR) with 95% confidence interval (95% CI).
The statistical software used were STATA SE version 14.0 (Stata Corp, College Station, TX, USA) and SPSS software, version 21 (SPSS, Inc, an IBM Company, Chicago, Illinois).

RESULTS

Descriptive data

After pooling data from all centers, a total of 178 patients fulfilled the eligibility criteria and were included in the study (Figure 1). One hundred and twenty-seven patients were men (71.3%) and 51 women (28.7%). Mean age was 33.1 years (14-66, SD 11.9). High energy trauma was the most usual mechanism of injury, present in 90 patients (50.6%), followed by sports trauma in 69 patients (38.8%) and low energy trauma in 15 (8.4%). Vascular injury was present in 5 cases (2.8%), with 34 cases (19.1%) not reporting this data. Nerve injuries affected 17 patients (9.6%) and was not reported in 34 patients (19.1%).

Figure 1. Flow diagram[a]



[a]MRI, magnetic resonance image.

Using the surgical data available, patients were classified according to Schenck classification: 72 (40.4%) showed a KDI lesion, 10 (5.6%) KDII, 33 (18.5%) KDIIIM, 39 (21.9%) KDIIIL and 22 (12.4%) KDIV. Final diagnosis of non-MLKI during surgery prevented to assign KD grade in 2 patients (1.1%).

Time from injury to MRI scan showed a median of 11 days (0-6119, SD 711.5) and was not reported in 9 cases (5.1%).

Reporting on MRI reports

The percentage of adequate description of different knee structures on MRI records was highly variable (Table 2): all MRI reports informed about their findings for the ACL, so ACL had the highest reporting percentage (100%), followed by MCL (99.4%), medial (98.9%) and lateral meniscus (98.3%) and PCL (97.8%). The PFL had the lowest reporting percentage (47.8%) followed by ILTT (58.4%) and BT (68.5%).

Table 1. Percentage of description of knee structures on MRI and surgical records[a]

Knee structure	MRI reports	Surgical records
ACL	100%	100%
PCL	97.8%	94.4%
MCL	99.4%	97.2%
FCL	94.9%	92.1%
PFL	47.8%	80.3%
PLT	71.9%	86.5%
ILTT	58.4%	78.7%
BT	68.5%	79.8%
MM	98.9%	97.2%
LM	98.3%	98.3%
CartT	92.7%	97.2%
CartF	93.8%	97.2%
CartPF	92.7%	97.8%

[a]MRI, magnetic resonance image; ACL, anterior cruciate ligament; PCL, posterior cruciate ligament; MCL, medial collateral ligament; FCL, fibular colateral ligament; PFL,

popliteofibular ligament; PLT, popliteus tendon; ILTT, iliotibial tract; BT, biceps tendon; MM, medial meniscus; LM, lateral meniscus; CartT, tibial cartilage; CartF, femoral cartilage; CartPF, patellofemoral joint cartilage.

Reporting on surgical records

Percentage of reported data on surgical records was higher than that from MRI reports, and ranged between structures (Table 2): ACL had the highest reporting percentage (100%), followed by lateral and medial meniscus (98.3% and 97.2%, respectively) whereas ILTT and BT had the lower reporting percentage, with 78.7% and 79.8% respectively.

Intraclass Correlation Coefficient

Intraclass correlation coefficient, diagnostic accuracy, diagnostic odds ratio, sensitivity, specificity, positive predictive value, negative predictive value, positive likelihood ratio and negative likelihood ratio are detailed in Table 3. ICC for average measures was excellent (>0.90) for BT and good (from 0.75 to 0.90) for ACL, PCL, MCL, FCL, PFL, PLT, ILTT, MM, LM, CartT, CartF and CartPF.

Diagnostic accuracy and diagnostic odds ratio

ACL, CartPF, CartT and PCL had the highest DA values, all over 90%. ILTT, BT, CartF, MCL, PFL and both meniscus ranged from 89 to 80% and PLT, with 76%, had the lowest DA.

DOR values highly varied among structures, with ACL, BT and PCL showing the higher values whereas PFL, FCL and PLT had the lowest.

Sensitivity, Specificity, PPV and NPV

The ACL (96.8%) and PCL (94.4%) showed the highest PPV for ligaments, while in contrast, the ILTT (56.3%), BT (59.3%) and PLT (72.5%) presented the lowest PPV. Differently, the BT (98.7%) and ILTT (97.2%) had the highest NPV, followed by the FCL (75.7%), PLT (78.9%) and ACL (79.2%) showed the lowest NPV.
In both medial and lateral meniscus, the MRI was more reliable detecting absence of lesions (specificity 87%, NPV 83.9% for MM and specificity 83.5%, NPV 81.8% for LM) than identifying presence of lesions (sensitivity 71.4%, PPV 76.3% for MM and sensitivity 76%, PPV 78.1% for LM).

Similarly as to the meniscus, the MRI showed good reliability to identify absence of chondral lesions, with specificity over 95% for tibial, femoral and patellofemoral cartilage injuries, but was less accurate in detecting presence of chondral lesions (sensitivity of 68% for tibia, 70.5% on femur and 64.7% for patellofemoral joint and PPV of 77.3% for tibia, 75.6% for femur and 68.8% for the patellofemoral joint).

TABLE 2. Diagnostic accuracy performance of MRI and inter-rater reliability[a]

Knee structure	ICC (95% CI, p-value)	Diagnostic accuracy	DOR (95% CI)	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	LR+ (95% CI)	LR- (95% CI)
ACL	0.82 (0.76-0.87, <.0001)	94.4%	113.2 (30.8-417.4)	96.8% (92.6-98.9)	79.2% (57.8–92.9)	96.8% (92.6-98.9)	79.2% (57.8-92.9)	4.6 (2.1-10.1)	0.04 (0.02-0.1)
PCL	0.86 (0.81-0.9, <.0001)	90.9%	71.04 (24.4-207.2)	93.6% (87.8-97.2)	82.9% (67.9-92.8)	94.4% (88.7-97.7)	81% (65.9-91.4)	5.5 (2.8-10.8)	0.08 (0.04-0.15)
MCL	0.82 (0.75-0.87, <.0001)	81.9%	22.4 (9.9-50.6)	89.7% (81.9-94.9)	72% (60.4-81.8)	80.6% (71.8-87.5)	84.4% (73.1-92.2)	3.2 (2.2-4.6)	0.1 (0.1-0.3)
FCL	0.83 (0.77-0.88, <.0001)	80.3%	17 (7.7-37.4)	79.8% (69.9-87.6)	81.2% (69.9-89.6)	84.5% (75-91.5)	75.7% (64.3-84.9)	4.2 (2.6-7)	0.3 (0.2-0.4)
PFL	0.81 (0.71-0.88, <.0001)	80.7%	17.5 (5.8-52.9)	87.5% (74.8-95.3)	71.4% (53.7-85.4)	80.8% (67.5-90.4)	80.6% (62.5-92.5)	3.1 (1.8-5.2)	0.2 (0.1-0.4)
PLT	0.77 (0.67-0.84, <.0001)	76.2%	9.9 (4.3-22.7)	71.2% (56.9-82.9)	80% (68.7-88.6)	72.5% (58.3-84.1)	78.9% (67.6-87.7)	3.6 (2.2-5.9)	0.4 (0.2-0.6)
ILTT	0.88 (0.82-0.92, <.0001)	89.6%	44.4 (8.7-100)	81.8% (48.2-97.7)	90.8% (81.9-96.2)	56.3% (29.9-80.2)	97.2% (0.2-99.7)	8.9 (4.2-19)	0.2 (0.1-0.7)
BT	0.91 (0.887-0.94, <.0001)	88.6%	112 (16.7-100)	94.1% (71.3-99.9)	87.5% (78.7-93.6)	59.3% (38.8-77.6)	98.7% (93.1-100)	7.5 (4.3-13.3)	0.1 (0.0-0.5)
MM	0.79 (0.71-0.84, <.0001)	81.3%	16.8 (7.7-36.6)	71.4% (58.7-82.1)	87% (79.2-92.7)	76.3% (63.4-86.4)	83.9% (75.8-90.2)	5.5 (3.3-9.2)	0.3 (0.2-0.5)
LM	0.81 (0.74-0.86, <.0001)	80.2%	16 (7.6-34)	76% (64.7-85.1)	83.5% (74.6-90.3)	78.1% (66.9-86.9)	81.8% (72.8-88.9)	4.6 (2.9-7.3)	0.3 (0.2-0.4)
CartT	0.89 (0.85-0.92, <.0001)	91.9%	56.1 (16.9-186.3)	68% (46.5-85.1)	96.4% (91.7-98.8)	77.3% (54.6-92.2)	94.3% (89.1-97.5)	18.6 (7.6-46)	0.3 (0.2-0.6)
CartF	0.82 (0.76-0.87, <.0001)	85.9%	26.2 (10.6-65)	70.5% (54.8-83.2)	91.7% (85.2-95.2)	75.6% (59.7-87.6)	89.4% (82.6-94.3)	8.5 (4.5-15.8)	0.3 (0.2-0.5)
CartPF	0.84 (0.78-0.88, <.0001)	93.2%	51 (13.8-188.6)	64.7% (38.3-85.8)	96.5% (92.1-98.8)	68.8% (41.3-89)	95.9% (91.2-98.5)	18.6 (7.4-47.2)	0.4 (0.2-0.7)

[a]ICC, intraclass correlation coefficient; CI, confidence interval; DOR, diagnostic odds ratio; PPV, positive predictive value; NPV, negative predictive value; LR+, positive likelihood ratio; LR-, negative likelihood ratio; ACL, anterior cruciate ligament; PCL, posterior cruciate ligament; MCL, medial collateral ligament; FCL, fibular colateral ligament; PFL, popliteofibular ligament; PLT, popliteus tendon; ILTT, iliotibial tract; BT, biceps tendon;

MM, medial meniscus; LM, lateral meniscus; CartT, tibial cartilage; CartF, femoral cartilage; CartPF, patellofemoral joint cartilage.

Logistic regression

Increased age displayed a correlation with worst diagnostic accuracy on ACL lesions both in univariate (OR, 1.1 [95% CI, 1-1.1] P = .03) and multivariate (OR, 1.1 [95% CI, 1-1.1] P = .013) analysis, as well as on CartF both in univariate analysis (OR, 1.1 [95% CI, 1-1.1] P = .004) and multivariate analysis (OR, 1.1 [95% CI, 1-1.1] P = .005). Male sex influenced MRI accuracy for ILTT both in univariate (OR, 0.2 [95% CI, 0.04-0.08] P = .028) and multivariate (OR, 0.13 [95% CI, 0.02-0.07] P = .018) analysis and for CartF both in univariate (OR, 4.7 [95% CI, 1-20.8] P = .044) and multivariate analysis (OR, 4.6 [95% CI, 1-21.1] P = .048). The diagnostic accuracy of other knee structures was not influenced by either age or sex.

Schenck classification affected diagnostic accuracy of MRI for ACL (OR, 0.4 [95% CI, 0.2-0.9] P = .032), PCL (OR, 0.5 [95% CI, 0.3-0.8] P = .005), PLT (OR, 1.4 [95% CI, 1.03-1.8] P = .032), ILTT (OR, 3.6 [95% CI, 1.3-10.3] P =. 017) and BT (OR, 2.4 [95% CI, 1.3-4.5] P = .005). Specifically, the higher was the Schenck grade, the lower was MRI diagnostic accuracy for peripheral structures: ILTT, PLT and BT. In contrast, for ACL and PCL, higher grades of Schenck improved the diagnostic accuracy of the MRI.

Mechanism of injury, time from lesion to MRI scan, magnetic field intensity of the MRI scan (measured in Teslas) and concomitant vascular and neurological lesions did not affected MRI accuracy for any of the analyzed knee structures.

DISCUSSION

The main finding of this study is that diagnostic accuracy of MRI reports highly varies for the different knee structures in MLKI, with some knee structures showing high risk of misdiagnosis. The diagnostic accuracy of MRI was mostly influenced by severity of the lesion (Schenck classification), and by age or sex for some knee structures. To our knowledge, this is the largest study on this topic to date, the one with the more detailed data and the first to find an association between Schenck´s grade and the DA of MRI.

Even though the first reports that analyzed MRI accuracy on dislocated knees found very good sensitivity and specificity for most of the studied structures,[5,16,23,26,30] with a PPV over 90% for all the major ligaments (ACL, PCL, PLC, MCL and patellar tendon),[26] those findings were not replicated in subsequent studies.[1,3,10] The small sample size of these initial studies,[5,16,23,26,30] together with the incomplete comprehension of the anatomy of the knee at the time, could explain their overestimation on the diagnostic accuracy of MRI to identify MLKI. Some of these studies did not include all types of MLKI lesions,[5,30] recorded incomplete data[26] and lacked statistical power[23,26,30] to reach firm conclusions.

Rubin et al,[24] conducted a study in 340 knee MRI´s, including knees without lesion, with one ligament torn and MLKI. They found a trend towards fewer diagnostic accuracy of MRI in the most complex lesions. They found a statistically significant difference in the specificity of MRI for patients with one or none ligaments torn versus those with two or more torn ligaments. The sensitivity for MM lesions dropped from 98% when there were no associated ligament lesions to 89% when one ligament was torn and 59% when two or more structures were torn. This was the first report to pin down this issue and its conclusions are similar to those reached in the present study. In our research, the logistic regression showed an influence of Schenck grade on the MRI DA for most knee structures (ACL, PCL, ILTT, BT and PT), improving accuracy for the central pivot (ACL and PCL), but decreasing it for peripheral structures (ILTT, BT and PT). This association is of special interest, as no previous study has reported it. Likewise, it highlights the risk of PLC and peripheral lesions misdiagnosis in MLKI, especially in the more severe ones. The better MRI diagnostic accuracy depicted for the central pivot in more severe knee lesions could be related to the fact that these lesions could associate more grossly torn ACL and PCL. Conversely, a lower diagnostic accuracy for peripheral structures (ILTT, BT and PT) in more severe lesions could be related to the more extensive soft-tissue injury and edema usually associated to high grade KD lesions,[3,10,16] that could artifact MRI images, making diagnosis of extra-articular lesions more challenging.

Logistic regression showed decreased MRI DA for ACL in older patients. This could be correlated with the changes of the ACL in older patients, that show weaker and thinner ligaments with smaller footprints of the direct insertion of the ACL.[19,20] It is known that ACL morphology is influenced by sex, [2] but no influence of sex in MRI DA for the ACL was found. In contrast, the correlation between sex and MRI DA for ILTT and femoral cartilage have not been previously described and could be the scope of future studies.

The intra and interobserver reliability of MRI evaluation to diagnose MLKI (using kappa coefficient) has been reported to be low.[1] This reliability increased as level of analysis was simplified[1]- i.e., it was more reliable to identify torn vs. intact structures rather than to assess the grade and location of the lesions. When level of analysis switched from detailed to simplified or binary, the interobserver reliability improved to moderate, but agreement between MRI reading and surgical findings remained low.[1] These findings pinpoint a concern about MRI reliability. In contrast, other study reached excellent kappa coefficient values (over 0.75) between MRI and surgery for ACL, PCL, MCL and FCL with regard to size and tendon tears location.[23] In our study, the ICC was good (over 0.75) for all knee structures and excellent for BT (0.9). The results from our study show a far better agreement between MRI and surgical findings, when analyzed as non-dichotomous variables, than those reported by Barbier et al[1] and similar to those reported by Potter et al.[23] These differences could not be attributed to difference in expertise of radiologist and surgeons involved in both studies, as the study by Barbier et al[1] included surgeons with varying grades of experience and found that experience was not correlated to reliability, and the radiologists involved in both studies[1,10] were experienced musculoskeletal radiologists, as in our study.

A few studies have reported that the MRI is not a reliable tool to diagnose injuries to the PLC, as it has varying specificity and low sensitivity.[3,10] These findings are similar to our results for the PLC injuries (FCL, PFL and PLT), but our values for sensitivity (71.2-87.5%) were higher than those of two previous studies.[3,10] Our results highlight the risk of misdiagnosis of PLC injuries with MRI, but find that sensitivity is not as low as previously reported. Regarding ACL and PCL injuries, even globally these two structures showed the better results in most of the studied parameters, we find lower values for specificity and NPV for both structures than previous studies.[3,10]

Menisci showed good diagnostic accuracy, and MRI was more reliable identifying cases without injury than identifying cases with injury. This highlights the risk of misdiagnosis of meniscal lesions associated to MLKI on MRI, and demonstrate that a diagnosis of meniscal lesion on MRI is more likely to fail than a diagnosis of absence of lesion. This finding is similar to previous studies[10,12] which consistently show that MRI reports on menisci were more reliable concerning specificity and NPV than sensitivity and PPV. Chondral lesions, similarly to menisci, are more likely to be under-diagnosed than over-diagnosed, as specificity and NPV were better than sensitivity and PPV. This is similar to the results reported by Halinen et al.,[12] where on a series of 44 patients with ACL and MCL injuries, none of 10 chondral lesions found during surgery were detected on MRI.

The results of our study, together with those from the scarce literature that had analyzed the diagnostic accuracy of MRI on MLKI,[1,3,5,10,12,16,23–25,30] highlight that orthopaedic surgeons should be aware of the potential risk of misdiagnosis of MLKI when relying only on MRI reports for surgical planning. Chondral and meniscal lesions have a high risk of misdiagnosis, similarly to the BT and the structures that comprises the PLC. Thus, their diagnosis should not solely rely on MRI reports,[1,3] but also be accompanied by a detailed clinical exam under anesthesia[1] together with stress radiographs,[1,9,13] to ensure an accurate diagnosis that allows proper surgical planning.

We are aware of the limitations of the present study. First, the retrospective design implies lack of some data, with some knee structures (PFL, PT, ILTT and BT) showing high percentage of non-report, especially in MRI records. We tried to counteract this limitation by enlarging sample size, that allowed us to reach statistical significance for all the studied structures as we reached the number of patients needed to reach statistical significance stated at the sample size calculation. Due to its retrospective and multicenter design, another limitation is the heterogeneity of the data (MRI acquisition sequences, different radiologists and surgeons evaluating the data), but that exemplifies real-world data. A major flaw of the study was the lack of a systematical assessment of the originals MRI films, and instead the radiologist´s MRI reports were reviewed. Even though, all MRI reports were informed by experienced musculoeskeletal radiologists, similarly to previous studies, [1,21,23,24]. Also, even the heterogeneity of the centers could be seen as a flaw, all the participants were experienced knee surgeons from reference centers, depicting a general scenario that could be similar to many specialized knee centers where these lesions are usually treated.

As many of the calculated parameters are prevalence dependent, these results could vary on populations with different prevalence. For this reason we calculated the DOR, since it gives outcomes valid for any population, as it is not a prevalence-dependent parameter. Time from injury to MRI varied among patients, with some of them having the MRI more than 3 weeks after injury. As MRI accuracy could vary from acute and chronic injuries,[10,13] this could have been a confounding factor. Time from MRI to surgery also varied between patients: as longer delays from MRI to surgery could lead to the appearance of new lesions associated to the instability,[3,10,14] especially meniscal and chondral lesions, this could had acted as a confounding factor. However, time from MRI to surgery was not associated with the diagnostic accuracy and thus potentially did not confounded our results.

On the other hand, the large sample size and the detailed data collection allowed us to establish correlations between the characteristics of the lesion and MRI accuracy in logistic regression. Further high-quality prospective studies, with standardized MRI scan protocols and standardized intraoperative exploration could improve our knowledge on MRI accuracy on MLKI and confirm or refute the correlations found in the present study.

CONCLUSION

The diagnostic accuracy of MRI findings in MLKI varies for the different knee structures, with the PLC, meniscal and chondral lesions showing high risk of misdiagnosis. The severity of the MLKI, according to Schenck classification, can significantly influence the diagnostic accuracy of MRI reports when evaluating MLKI. Orthopaedic surgeons should be aware of the potential risk of misdiagnosis when relying on MRI findings for surgical planning and that the more severe MLKI are associated with lower diagnostic accuracy for the ILTT, PLT and BT.

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Appendix. MRI scans characteristics[a]

CENTER	MRI system	Sequence	Knee position	Time to repetition	Time to echo	FOV	Matrix (phase × frequency)	Slide thickness	Slide spacing
1	1.5-T (MAGNETOM Avanto, Siemens Healthcare, Erlangen, Germany)	Sagittal T1-weighted	Full extension	578 ms	11 ms	NR	NR	3 mm	NR
		Sagittal PD		3460 ms	13 ms	NR	NR	3 mm	NR
		Coronal PD		3180 ms	13 ms	NR	NR	3 mm	NR
		Axial PD		2240 ms	13 ms	NR	NR	4 mm	NR
2	Signa Creator 1.5-T (General Electrics, USA)	Sagital PD FS	NR	2300 ms	35 ms	16	320x224	4 mm	0.5 mm
		Coronal PD FS	NR	2000 ms	35 ms	16	288 x 224	4 mm	1 mm
		Axial DP FS	NR	2143 ms	20 ms	16	256 x 256	4 mm	1 mm
		Sagital Cube PD FS	NR	1500 ms	25 ms	16	224 x 224	2 mm	0.5 mm
		Sagital PD FSE ACL	NR	2000 ms	35 ms	17	256 x 192	2 mm	0.5 mm
	Canon Elan 1.5-T (Canon Medial Systems SA)	Axial SE PD FS	NR	NR	NR	NR	NR	NR	NR
		Sagital SE T1	NR	NR	NR	NR	NR	NR	NR
		Sagital SE DP FS	NR	NR	NR	NR	NR	NR	NR
		Coronal T2 FS	NR	NR	NR	NR	NR	NR	NR
3	Achieva (Philips, 1.5 or 3.0 T) Skyra (Siemens, 3.0 T) Esprit (Siemens, 1.5 T)	Sagittal T2	Full exten sion	NR	NR	NR	NR	1.5mm	NR
		Coronal T1		NR	NR	NR	NR	4 mm	NR
		Axial T2		NR	NR	NR	NR		NR
4	NR	NR	NR	NR	NR	NR	NR	NR	NR
5	NR	NR	NR	NR	NR	NR	NR	NR	NR
6	1.5-T (MAGNETOM Avanto, Siemens Healthcare, Erlangen, Germany)	Sagittal T1-weighted	Full extension	578 ms	11 ms	NR	NR	3 mm	NR
		Sagittal PD		3460 ms	13 ms	NR	NR	3 mm	NR
		Coronal PD		3180 ms	13 ms	NR	NR	3 mm	NR
		Axial PD		2240 ms	13 ms	NR	NR	4 mm	NR
7	3.0-T (Siemens, Erlan-gen, Germany)	Sagittal, coronal, and axial sequences using both PD- and FS PD-weighted	Full extension	3000-400 0 ms	33-3 5 ms	130 mm	320 × 320 and 384 × 384 mm	3 mm	NR

[a]MRI, magnetic resonance image; T, teslas; NR, non reported data; FOV, field of view; ms, milliseconds; mm, millimeters; PD, proton density; FS, fat suppressed; FSE, fast spin echo; SE, spin echo.