The Value of MRI in Diagnosing and Classifying Acute Traumatic Multiple Ligament Knee Injuries

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Abstract

Background Magnetic resonance imaging (MRI) is a widely used examination for knee injuries, however, the accuracy of MRI in classifying multiple ligament knee injuries (MLKIs) has not been reported. The purpose of this study was to investigate the value of MRI in diagnosing and classifying acute traumatic MLKIs.

Methods The clinical data of 97 patients who were diagnosed with acute traumatic MLKIs and managed by multi-ligament reconstruction were retrospectively reviewed. Intraoperative findings were considered as the standard pattern of injured structures. The value of MRI in detecting injuries of ligaments and meniscus was evaluated by calculating the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio (PLR), negative likelihood ratio (NLR), and kappa coefficients analysis. The value of MRI in classifying MLKIs was evaluated by calculating the agreement between MRI and intraoperative findings.

Results For detecting the specific injured structures in MLKIs, MRI had high sensitivity and moderate specificity in detecting cruciate ligament injuries, moderate sensitivity and specificity in detecting collateral ligament injuries, fair sensitivity and low specificity in the diagnosis of injuries to the meniscus. For classifying the MIKIs, MRI had a moderate agreement with intraoperative findings in classifying KD-□ (kappa value=0.57), poor agreement in the KD-□ (kappa value=0.39) and KD-□M (kappa value=0.31), meaningless in the KD-□ and KD-□L (kappa value <0). The overall agreement in classifying MLKIs was poor (kappa value =0.23).

Conclusions MRI can be used for the early detection of MLKIs, however, the value of MRI in classifying MLKIs is limited, management of MLKIs should be based on intraoperative findings.

Introduction

Multi-ligament knee injuries (MLKIs) are rare but serious injuries that are usually caused by high-energy trauma, such as car accidents, injuries of falling, and injuries caused by machines [1–3]. The diagnosis of MLKIs should be based on the physical examination, imaging examination, and intraoperative findings. The definition of MLKIs including injuries of at least two in the cruciate and collateral ligaments, with or without injuries of meniscus, nerves, arteries, or periarticular fractures [4]. Some of the MLKIs had knee dislocations (KD), however, the dislocated knee can reduce spontaneously or have been reduced in the emergency department before hospitalization, thus the severity of the injured knee can be underestimated [1, 5, 6], and MLKIs represents more injury patterns than KD. Early detection of injured structures is crucial for the management of MLKIs, MRI is the necessary preoperative examination for ligament injuries, which is also valuable in detecting nerve injuries [7]. However, the accuracy of MRI in classifying MLKIs has not been reported. This study aimed to investigate the value of MRI in diagnosing and classifying acute traumatic MLKIs.

Methods

Patients

The database of knee surgeries between 2012 and 2020 was retrospectively reviewed. Patients who were diagnosed with MLKIs and treated by multi-ligament reconstruction were included. The inclusion criteria were (1) Acute traumatic multi-ligaments injuries of at least two among the ACL, PCL, MCL, and LCL. (2) The 1.5 tesla MRI was performed preoperatively and the imaging was available. (3) The injury patterns of knee structures were detailed recorded in surgical notes. The exclusion criteria were (1) Revision of failed reconstructed ligaments. (2) Periarticular tumors, infections, or congenital disorders were found during the surgery. After admission, a standard 1.5-Tesla MRI using the Turbo Spin Echo (TSE) technique, including proton density (PD), T2- and T1-weighted sequences, and fat suppression technique was performed. Perioperative X-Rays, CT scans were also performed to observe whether there were periarticular fractures and other lesions. Computed tomographic angiography (CTA) was performed to identify the injuries of arteries. All patients underwent a standard physical examination of the injured knees under anesthesia, including the Lachman test, the anterior and posterior drawer test, the valgus test, the varus test, the dial test, the pivot-shift test, the reverse pivot-shift test, and the McMurray test. The results were compared with the uninjured knee, and side-to-side differences were recorded. General information including the age, gender, mechanisms of the injuries was recorded.

Evaluation of the diagnostic value of MRI

The MRI imaging was analyzed by two musculoskeletal radiologists independently to check the presence of injuries to ACL, PCL, MCL, LCL, PLC, and meniscus, either partial tear, complete tear, or avulsion of the ligament endpoints. The injured ligaments and meniscus were compared with intraoperative findings that were extracted from the surgical records. Periarticular fractures presented in MRI including fractures of the femoral condyle, tibial plateau, tibial intercondylar eminence, patella, and fibula head. The bone contusion, edema of bone marrow, and bony avulsion of ligaments were not regarded as periarticular fractures. The reference standard of periarticular fractures was identified through preoperative X-ray, CT scan, and intraoperative findings either from an open or arthroscopic approach.

The kappa statistics were used to determine the agreement between MRI and intraoperative findings. The diagnostic value of MRI was evaluated by calculating the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio (PLR), negative likelihood ratio (NLR), accuracy, and kappa value. The sensitivity, specificity, and accuracy were defined as high (≥85%), moderate (65%-85%), fair (50%-65%), low (<50%). The MLKIs were classified according to Schenck et al [8], the classification based on MRI and intraoperative findings was compared, and the agreement was evaluated by calculating the kappa value. The agreement was defined as good (*kappa* value≥0.75); moderate (0.4≤*kappa* value <0.75), poor (*kappa* value <0.4); meaningless (*kappa* value≤0).

Statistical analysis

SPSS 25.0 (IBM Corp., Armonk, NY, USA) was used for statistical analyses. The normality of the quantitative data was checked by the Kolmogorov-Smirnov test. Normally distributed quantitative data were expressed by Mean ± Standard Deviation (*SD*), non-normal distributed quantitative data were presented as the interquartile range (*IQR*). Qualitative data were presented as numbers and percentages. Kappa analysis was used to evaluate the agreement between MRI results and intraoperative findings, and the agreement between two radiologists. The significant level was defined as 0.05.

Results

Study cohort

Ninety-seven patients (97 injured knees) were included for analysis. There were 69 males (71.1%) and 28 females (28.9%), the mean age was 41.3 (±1.7) years. The MLKIs were classified as 20 KD-I (20.6%), 4 KD-□ (4.1%), 47 KD-□M (48.5%), 5 KD-□L (5.2%), and 21 KD-□ (21.6 %) according to intraoperative findings.

Diagnostic value of MRI

The agreement between the two radiologists was good ((*kappa*=0.83, *P*<0.001). MRI was found to have high sensitivity (90.7 %) and moderate specificity (63.6%) in the diagnosis of injuries to the ACL; high sensitivity (90.4 %) and moderate specificity (50%) in the diagnosis of injuries to the PCL; moderate sensitivity (79.1%) and low specificity (46.7%) in the diagnosis of injuries to the MCL; fair sensitivity (55.6%) and moderate specificity (68.4%) in the diagnosis of injuries to the LCL; fair sensitivity (61.5%) and low specificity (39.4%) in the diagnosis of injuries to the meniscus. The accuracy was good for ACL injuries (87.6%) and PCL injuries (84.5%), moderate for MCL injuries (69.1%) and LCL injuries (66.9%), low for the meniscus injuries (45.4%). The agreement between MRI results and intraoperative findings was moderate in the ACL injuries (*kappa*=0.47) and PCL injuries (*kappa*=0.39), poor in the MCL injuries (*kappa*=0.26) and LCL injuries (*kappa*=0.18), and meaningless in tears of the meniscus (Table 1). Only one of the 9 injured PLC was revealed by preoperative MRI, so the sensitivity and specificity cannot be calculated. The preoperative MRI images of the injured ligaments were shown in Figure 1.

Of the 97 combined injuries, 7 cannot be classified by preoperative MRI findings. 13 KD-□ (65%), 3 KD-□ (30%), 22 KD-□M (50%), 1 KD-□L (12.5%), 12 KD-□(80%) were successfully classified by MRI. In total, the classification based on MRI results and intraoperative findings was the same in 51 patients (52.6%). The kappa statistics showed that MRI has a moderate agreement with intraoperative findings in classifying KD-□ (*kappa* value=0.57), poor agreement in the KD-□ (*kappa* value=0.39) and KD-□M (*kappa* value=0.31), while meaningless in the KD-□ and KD-□L (*kappa* value <0). The overall agreement in classifying MLKIs was poor (*kappa* value =0.23) (Table 2).

Discussion

The present study found that the accuracy of MRI was good for detecting cruciate ligament injuries, moderate for collateral ligament injuries, low for meniscus injuries. We retrieved the literature and confirmed that this is the first study that investigating the value of MRI in classifying the MLKIs. Though MRI performs better in classifying Schenck-□ MLKIs, the overall agreement with intraoperative findings was poor. In short, MRI helps early detection of MLKIs, however, it has limited value in classifying the MLKIs preoperatively. The management of MLKIs should be based on intraoperative findings.

The value of MRI diagnosis concerning isolated ligament injuries has been widely proved, however, in terms of multi-ligament injuries, the accuracy of MRI is controversial. Derby et al [9] investigated the sensitivity and specificity of 1.5 Tesla MRI for diagnosing injuries of knee dislocation, he found that MRI has high sensitivity but low specificity for tears in the cruciate and collateral ligaments; low sensitivity but high specificity for injured PLC, it was not reliable for injuries of the meniscus. Twaddle et al [10] compared results of clinical, MRI, and surgical findings of 17 dislocated knees, MRI results were more reliable than clinical examination compared to intraoperative findings. However, Lonner et al [11] reported opposite results in 10 patients with acute traumatic knee dislocations, they thought the clinical examination under anesthesia was more precise. Halinen et al [12] compared MRI with examination under anesthesia to surgical findings in 44 patients with acute ACL and MCL combined injuries, MRI presented a 93.2% accuracy and sensitivity for the severe ACL tear, it was 86.4% for MCL, but MRI can not reveal the chondral lesion. Similar results were found by Munshi et al [13]. In terms of nerve injury, Reddy et al. [7] found that MRI has high sensitivity in detecting subclinical nerve injury, the injury of the common peroneal nerve is usually more severe than the tibial nerve. Research has suggested that oblique coronal and oblique sagittal MRI, which was parallel to the long axis of the ACL, improved the accuracy of the diagnosis of an ACL tear and the grading of ACL injury [14–16]. However, the application of oblique MRI in multiple ligaments injuries is limited. In the present study, we found that MRI has high sensitivity and moderate specificity in the rupture of cruciate ligaments, which was consistent with previous studies, but we found moderate sensitivity and specificity in the diagnosis of injuries to collateral ligaments. Intraoperative findings are usually considered the gold standard for diagnosing ligament injuries. However, the assessment and interpretation of MRI results should also be considered [17]. Barbier et al [18] investigated the relevancy and reproducibility of MRI interpretation of MLKIs and knee dislocations, they found that there was a low agreement between the surgeon's results, radiologist's results, and surgical data.

This is the first study investigating the value of MRI in classifying MLKIs according to Schenck classification. We find that MRI has a moderate agreement in classifying KD-V, poor agreement in classifying KD-□ and KD-□M, meaningless in KD-□ and KD- □L. We speculate that the meaningless agreements in the KD-□ and KD-□L were due to the small numbers of those two injuries, the diagnostic value cannot be reflected well. Though inferior to the CT scan, the present study revealed that MRI helps detect periarticular fractures. Besides, we found that MRI has high sensitivity in detecting ACL and PCL injuries, but the overall agreement was poor compared to intraoperative findings. The results were not surprising because the MLKIs are complex injuries, a precise MRI-based classification is challengeable. Though the sensitivity and specificity in this study differ from previous studies, we concluded MRI has limited value in classifying MLKIs preoperatively, thus the clinical management of MLKIs should be based on intraoperative findings.

In the present study, only one of the PLC injuries was revealed by preoperative MRI, suggesting a limited value of MRI in detecting PLC injuries, there were no false-positive cases, the sensitivity and specificity were not calculated because the number of samples was small. In fact, a few studies have reported the results of PLC reconstruction because of the low incidence rate. Derby et al [9] investigated the value of MRI in detecting the PLC for patients with knee dislocations, including LCL, iliotibial tract, popliteal tendon, and biceps. For LCL, The accuracy was 76 %, sensitivity was 100 %, specificity was 67 %, for the iliotibial tract, the accuracy was 89 %, specificity was 97 %, the sensitivity was not calculated because there were no true positives. In the present study, there were only 9 cases were diagnosed with PLC injuries according to the intraoperative findings. Since the injuries of PLC are rare in the MLKIs, precise detection of the PLC injuries in MRI is challenging. The value of MRI in detecting PLC injuries remains unknown, the diagnosis should be based on clinical examination under anesthesia and intraoperative findings.

The present study has some limitations. This is a retrospective analysis with a small number of samples. The severity of the injured ligaments was not graded in the MRI imaging, Furthermore, MRI results were not compared with clinical examination. Future studies should be based on larger samples and a more specific evaluation system.

Conclusions

This study revealed that MRI has high sensitivity but moderate specificity in detecting ACL and PCL injuries, and a fair agreement in classifying KD-V MLKIs. In short, MRI was found with limited value in classifying MLKIs, management of MLKIs should base on intraoperative findings.

Declarations

Ethical approval guidelines and consent to participate

This study was conducted in accordance with the ethical guidelines of the Declaration of Helsinki. This retrospective study was approved by the Research Ethics Committee of the General Hospital of Ningxia Medical University. Informed consent was obtained from all patients for this study, all patients agreed to participate in the study.

Consent for publication

All patients agreed to have their data published.

Availability of data and material

All data generated or analyzed during this study are included in this published article.

Competing interests

The authors declare that there is no conflict of competing financial and non-financial interests.

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Authors contributions

Haifeng Yuan design the study and censored the manuscript. Xusheng Li collected the data and drafted the manuscript. Qian Hou collected the data and performed the statistical analysis. Xiaobing Ma, Xuehua Zhan, and Long Chang analyzed the MRI results. All authors read and approved the final manuscript.

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Tables

Table 1 The diagnostic value of MRI in the MLKIs

	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	PLR	NLR	Accuracy (%)	Kappa value*	*p* value#
ACL	90.7	63.6	95.1	46.7	2.5	0.2	87.6	0.47	<0.001
PCL	90.4	50	91.5	46.7	1.8	0.2	84.5	0.39	<0.001
MCL	79.1	46.7	76.8	50	1.5	0.5	69.1	0.26	0.010
LCL	55.6	68.4	28.6	87.1	1.8	0.7	65.9	0.18	0.057
Meniscus	61.5	39.4	27.1	73.7	1.0	0.9	45.4	0.01	0.931

PPV positive predictive value; *NPV* negative predict value; *PLR* positive likelihood ratio; *NLR* negative likelihood ratio

*** The agreement was good (kappa value≥0.75); moderate (0.4≤kappa value<0.75); poor (kappa value<0.4); meaningless (kappa value<0)

If p<0.05, the agreement is significant

Table 2 The value of MRI in classifying MLKIs according to Schenck classification (n)

Intraoperative classification (n)	MRI classification (n)							Total (n)	Kappa value[#]	p value[&]
	□	□	□M	□L	□	□	NA*			
□	13	n.s.	1	1	4	n.s.	1	20	0.39	0.019
□	2	3	2	1	2	n.s.	n.s.	10	-0.07	0.619
□M	1	8	22	4	6	n.s.	3	44	0.31	0.003
□L	n.s.	4	1	1	1	n.s.	1	8	-0.21	0.262
□	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
□	n.s.	n.s.	n.s.	1	n.s.	12	2	15	0.57	0.007
Total	16	15	26	8	13	12	7	97	0.23	0.001

* Cannot be classified by Schenck classification

*The agreement was good (kappa value≥0.75); moderate (0.4≤kappa value<0.75); poor (kappa value<0.4); meaningless (kappa value<0)

If p<0.05, the agreement is significant

Figures

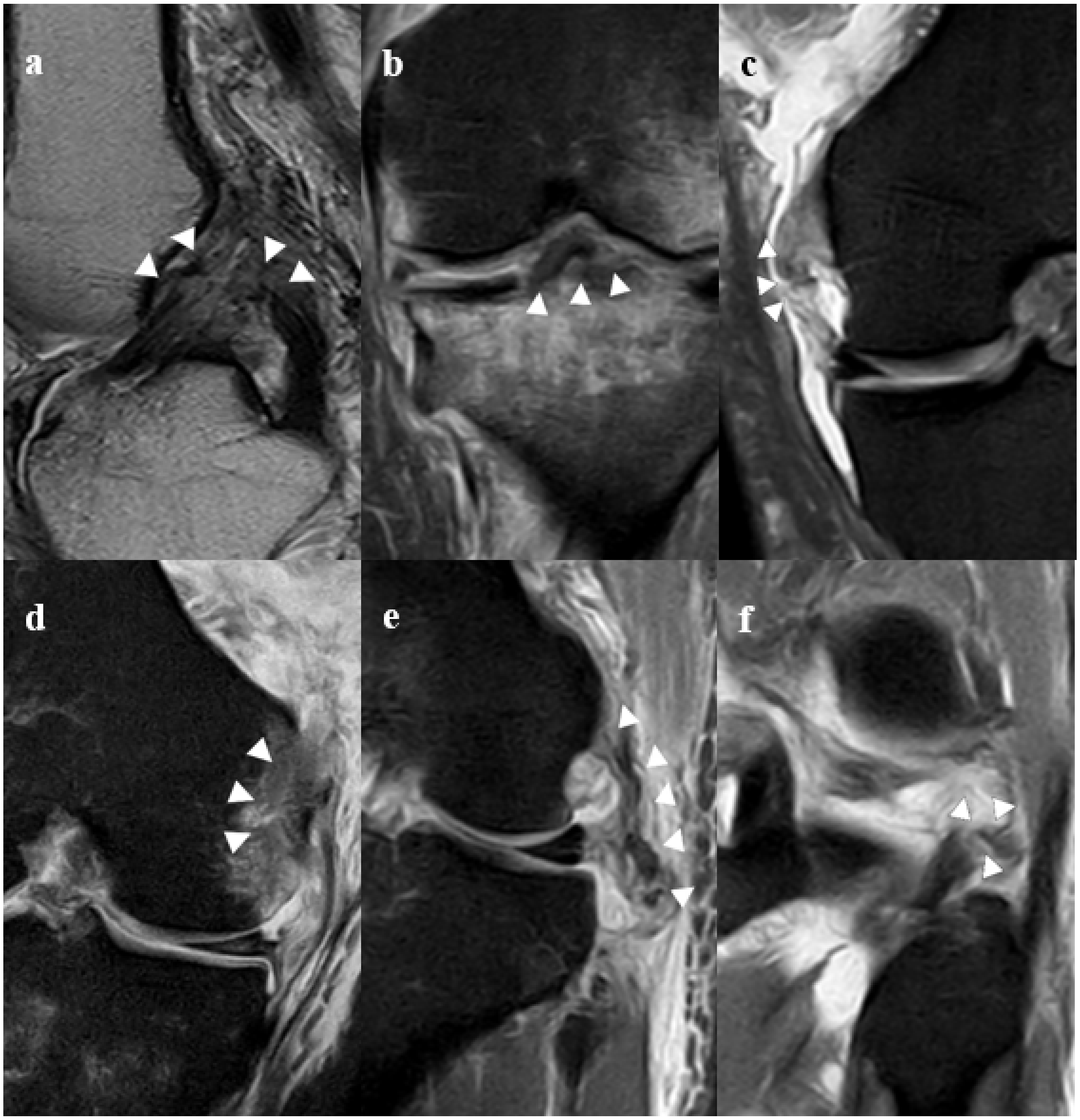

Figure 1

Preoperative MRI of the multiple ligaments knee injuries/knee dislocations; a The ruptured ACL and PCL; b Avulsion fracture at the ACL insertion in the tibial intercondylar eminence; c Rupture of MCL in the mid-substance; d Avulsion of MCL at the insertion of the femoral condyle; e The ruptured LCL in the mid-substance; f The ruptured popliteal tendon