Original Article

The Role of Diffusion-weighted Magnetic Resonance Imaging in the Evaluation of Anterior Cruciate and Posterior Cruciate Ligament Tears

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ABSTRACT

Objective: The objective of our study was to determine the role of diffusion-weighted (DW) magnetic resonance imaging (MRI) in diagnosing and differentiating between complete and partial anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL) tears and to compare it with conventional MRI sequences.

Materials and Methods: We conducted a prospective study for a period of 2 years from October 2017 to October 2019 on 30 patients with clinically suspected ACL/PCL injuries of the knee. MRI of the knee joint was performed using conventional, and DW sequences and the findings on both the sequences were assessed independently and compared with the intraoperative or follow-up MRI findings.

Results: As per operative and follow-up MRI findings, the sensitivity and specificity of conventional MRI were 60% and 33.33% with a positive and negative predictive value of 47.37% and 45.45%, respectively. On the other hand, the sensitivity and specificity of DW MRI were 70.00% and 33.33% with a positive and negative predictive value of 51.22% and 52.13%, respectively. $P = 0.417$ was statistically not significant.

Conclusion: According to our study, adding DW sequence to conventional MR sequences yielded comparable results in diagnosis and differentiation between complete and partial ACL and PCL tears.

Keywords: Anterior cruciate ligament, Posterior cruciate ligament, Magnetic resonance imaging, Diffusion-weighted sequence

INTRODUCTION

The cruciate ligaments are important structures in maintaining the normal stability of the knee with anterior cruciate ligament (ACL) being the most commonly injured ligament. Most ACL tears (nearly 80%) are complete, usually occurring around the middle one-third of the ligament (90%), or uncommonly close to the femoral (7%) or tibial (3%) attachments.[1] Magnetic resonance imaging (MRI) of the knee joint is routinely performed for the diagnosis of tear of cruciate ligaments. However, in some cases, differentiation between complete and incomplete tears is tough because the ligament fibers may be obscured by edema.[2] Ligament fibers have been shown to be better visualized on apparent diffusion coefficient (ADC) mapping and therefore, ADC mapping may be able to verify if the ligament is continuous or not.[3] Accurate diagnosis of incomplete tears is necessary to provide non-operative management in patients.

MATERIALS AND METHODS

Study design

We performed a prospective study at our institution for a period of 2 years from October 2017 to October 2019, which comprised 30 patients. Inclusion criteria included patients of age group 15–70 years with clinically suspected ACL/posterior CL (PCL) injuries. Exclusion criteria included patients who had undergone knee surgery or those with contraindications to MR imaging.

MRI protocol

All patients underwent MRI imaging on Philips Achieva dStream 1.5 Tesla MRI using sense body coil with parameters is shown in Table 1.

RESULTS

Out of 30 subjects, 27 cases were positive for ACL tear, 2 for PCL tear, and 1 for both ACL and PCL tear. The diagnosis and differentiation between complete and partial cruciate ligament tears were done on both conventional and diffusion-weighted (DW) sequences, and the findings were assessed independently. Nineteen subjects were operated and the MR findings were compared with the intraoperative findings. Remaining 11 patients underwent a follow-up MR imaging.

One case in our study showed partial ACL tear on conventional MR and complete tear on DW MR sequence, as shown in Figure 1. Intraoperative findings showed a complete tear of ACL. Another case showed complete tear of ACL on conventional MR and partial tear on DW MR sequence. The patient showed improvement in conservative management. Follow-up MRI was done which revealed partial tear of ACL, as shown in Figure 2. The third case showed partial tear of ACL on conventional MR and complete tear on DW sequence with partial tear seen intraoperatively, as shown in Figure 3. Furthermore, one case showed partial tear of PCL on conventional MR, whereas complete tear was seen on DW MR sequence, as shown in Figure 4. Intraoperative findings revealed a complete tear of PCL.

Table 1: MR sequence parameters.

Sequences	TR	TE	THK	FOV	NSA
PD SPAIR SAG	2500–5000	30	3.0/0.7	180	2
PD SPAIR TRA	2500–5000	30	3.0/0.7	180	2
PD SPAIR COR	2500–5000	30	3.0/0.7	180	2
T1W TSE SAG	450–500	15-25	3.0/0.7	180	2
DWI SAG	6200	110	4/0	170	4

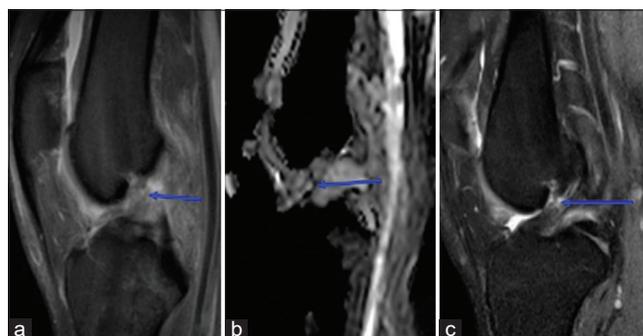SPAIR: Spectral attenuated inversion recovery, PD: Proton density

Statistical analysis

As per the operative findings in 19 subjects, the sensitivity and specificity of conventional MRI were 84.21% and 10.53% with a positive and negative predictive value of 48.48% and 40%, respectively, while the sensitivity and specificity of DW MRI were 94.74% and 10.53% with a positive and negative predictive value of 51.43% and 66.67%, respectively. $P = 0.290$ was statistically not significant, as shown in Table 2.

Follow-up MRI was done in the remaining 11 patients using conventional and DW sequences. The sensitivity and specificity of conventional MRI were 18.18% and 72.73% with a positive and negative predictive value of 40% and 47.06%, respectively, while the sensitivity and specificity
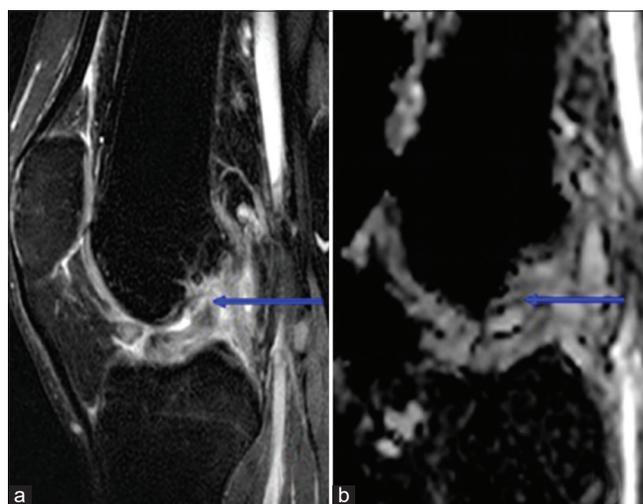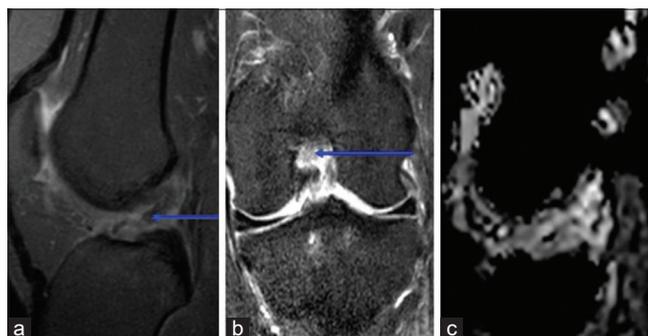

Figure 1: (a) Sagittal proton density spectral attenuated inversion recovery image showing partial tear of anterior cruciate ligament (ACL) (b) apparent diffusion coefficient mapping showing a complete tear. Intraoperative findings revealed a complete tear of ACL.

Figure 2: (a) Sagittal proton density (PD) spectral attenuated inversion recovery (SPAIR) magnetic resonance (MR) image showing complete anterior cruciate ligament tear (b) apparent diffusion coefficient mapping showing some intact anterior cruciate ligament fibers suggestive of partial tear (c) follow-up PD SPAIR MR image showing partial tear. The patient was managed conservatively.

of DW MRI were 9.09% and 72.73% with a positive and negative predictive value of 25% and 44.44%, respectively.

Figure 3: (a) Sagittal and (b) coronal proton density spectral attenuated inversion recovery magnetic resonance images showing partial tear of anterior cruciate ligament (c) apparent diffusion coefficient mapping showing non visualization of intact fibers suggestive of a complete tear. The intraoperative findings revealed partial tear.

Figure 4: (a) Sagittal and (b) coronal proton density spectral attenuated inversion recovery magnetic resonance images showing partial tear of posterior cruciate ligament (PCL) (c) apparent diffusion coefficient mapping showing complete PCL tear. Intraoperative findings showed a complete tear of PCL.

$P = 0.534$ was statistically not significant, as shown in Table 3.

As per operative and follow-up MRI findings, the sensitivity and specificity of conventional MRI were 60.0% and 33.33% with a positive and negative predictive value of 47.37% and 45.45%, respectively, while the sensitivity and specificity of DW MRI were 70.00% and 33.33% with a positive and negative predictive value of 51.22% and 52.13%, respectively. $P = 0.417$ which was statistically not significant, as shown in Table 4.

DISCUSSION

DW imaging is based on the diffusion of free water in tissue. Tissues rich in free water have a high diffusion coefficient and give a hyperintense signal on ADC mapping.[4] A ligament fragment has abundant collagen and little water and thus appears hypointense on ADC mapping. Hence, the study was undertaken based on the fact that ligament fibers would be better seen on ADC map, making it easier to ascertain the continuity of the ligament.[5]

Table 2: Correlation of conventional MRI and DW MRI as per operative findings.

MRI findings	Conventional MRI		DW MRI	
	n	Agr (%)	*n*	Agr (%)
Complete tear	16	84.21	18	94.74
Partial tear	3	15.79	1	5.26
Total	19	100.00	19	100.00

MRI: Magnetic resonance imaging, DW: Diffusion-weighted

Table 3: Correlation of conventional MRI and DW MRI as per follow-up MRI findings.

MRI findings	Conventional MRI		DW MRI	
	n	Agr (%)	*n*	Agr (%)
Complete tear	2	18.18	1	9.09
Partial tear	9	81.12	10	90.91
Total	11	100.00	11	100.00

MRI: Magnetic resonance imaging, DW: Diffusion-weighted

Table 4: Correlation of conventional MRI and DW MRI as per operative and follow-up MRI findings.

MRI findings	Conventional MRI		DW MRI	
	n	Agr (%)	*n*	Agr (%)
Complete tear	18	60.00	21	70.00
Partial tear	12	40.00	9	30.00
Total	30	100.00	30	100.00

MRI: Magnetic resonance imaging, DW: Diffusion-weighted

There was a study conducted by Delin *et al*. on 85 patients to determine the reliability and accuracy of DW MRI in combination with conventional MRI in distinguishing between complete and incomplete ACL tears. The study concluded that ADC mapping in association with conventional MRI is a reproducible method to more accurately differentiate between complete and incomplete ACL tears.[3]

Park *et al*. studied the usability of the quantitative evaluation of DW MRI in the diagnosis of ACL tears in 74 patients. The sensitivity and accuracy of DW imaging were found to be lower than the conventional MRI. Hence, adding DW imaging to conventional MR imaging did not significantly improve diagnostic performance.[6]

Van Dyck *et al*. studied the role of three Tesla MRI of ACL of the knee in differentiating complete from incomplete tears and concluded that MRI at 3.0 Tesla is a highly accurate method for identification of ACL tears. However, the accurate distinction between complete and incomplete ACL tears and recognition of incomplete tears of the ligament is still difficult, even at 3.0 Tesla.[7]

One case, in our study, showed partial ACL tear on conventional MRI while complete tear was seen on DW sequence and on arthroscopy. Another case showed partial PCL tear on conventional MRI and complete PCL tear on DW sequence. Intraoperative findings revealed a complete tear of PCL. Furthermore, one case showed complete ACL tear on conventional MRI and partial tear on DW sequence and on follow-up MRI, indicating that DW sequence could be more reproducible in distinguishing between complete and incomplete ACL and PCL tears.

The drawback of our study is the small sample size. A higher sample size could have helped us to find more significant results. Furthermore, surgical confirmation of findings on MRI was not available in all cases in our study.

CONCLUSION

In our study, we found out that adding DW sequence to conventional MR sequences yielded comparable results in diagnosis and differentiation between complete and partial ACL and PCL tears. However, due to small sample size in our study, more studies are warranted in this regard.

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Conflicts of interest

There are no conflicts of interest.

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