# ASSESSMENT OF ANTERIOR CRUCIATE LIGAMENT INJURIES USING MRI SPECIAL IMAGING APPROACHES

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**ABSTRACT**

This study was performed to evaluate the accuracy of MRI with sagittal oblique planning to additional sequences includes Proton Density (PD) fat saturated and Diffusion Weighted Imaging (DWI) correlated with Apparent diffusion coefficient (ADC) mapping for Anterior Cruciate Ligament (ACL) knee imaging. The data of this study was collected from a patient with knee joint diseases from the radiology department in the King Salman Hospital in the Hail Region. This study was done in the period from January 2022 to June 2022. It consists of Sixty-seven patients who conducted this retrospective study by 3T Siemens MR system. This study showed that, of the 67 (100%) patients, 23 (34.3%) patients were diagnosed with complete tears and 16 (24%) with partial tears. Among these traumatic patients, the diagnostic sensitivity and specificity for using approach C were (94%) and (95%) with a complete ACL tear and (90% and 96%) for a partial tear. With all interpretive conditions, Approach A represents lower statistical values. The sagittal oblique planning with PD fat saturated, DWI, and ADC map technique is helpful in many ACL abnormalities. Our data demonstrated that DWI-correlated ADC mapping is efficacious in the work-up of patients suspected to have ACL partial or complete tears according to its high sensitivity, specificity, and accuracy values. The appropriate use of sagittal oblique planning in managing ACL injury patient. DWI and ADC map sequence had a highly reliable diagnosis, mainly if there is a suspected difference between partial and complete tear or poor definition ACL.

## Introduction

The knee joint is formed by the intersection of two cruciate ligaments to connect the femur and tibia, maintaining their correct position. The knee joint becomes unstable when torn by one or both of these ligaments [1].

A cruciate ligament rupture often affects the anterior ligament. Stadium injuries are always the most common laceration causes, such as a sprained knee during ice skating or a collision in a sport that uses the ball. When the cruciate ligament is torn, severe swelling occurs in the knee joint, causing pain and tingling. In many cases, the cruciate ligament rupture is accompanied by a crackling and pitting sound, and the patient feels a concussion in the knee joint and cannot move his knee fully. To repeat the

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knee to its normal state and avoid joint erosion and inflammation, the orthopedic surgeon must either sew the cruciate ligament or replace it by implanting a muscle tendon [2, 3].

Ordinarily, the laceration of two-segment fibers of the anterior ligament is foremost during sports trauma. In many cases, the damage occurs due to the leg deviation from the bone axis (torsion). The following situations are typical of this type of injury: a violent collateral collision of the opponent with the knee joint in the football, extension of the knee joint, suddenly stopping movement while running at full speed, sudden change of direction while running at full speed, and nasty fall when jumping or turning [4-8].

**Materials and Methods**

This issue will be conducted regionally in Saudi Arabia, Hail region, in King Salman Specialist Hospital (KSSH). The study was performed from January 2022 to June 2022. 3-Tesla Siemens Magnetom Skyra MR system (Siemens, Erlangen, Germany) with a coil's fifteen channels, MRI parameter as shown in **(Table 1)**. A retrospective study design evaluated the accuracy of sagittal oblique planning for ACL knee imaging with different sequences to appreciate patients' degrees of ACL injury. In addition, the results will be compared with a standard knee imaging protocol to detect the reliability of the test was all examined.

**Table 1.** MRI parameter

| Parameters | T2W-TSE (axial) | PDW-fs (coronal) | PDW-fs (Sagittal) | T1W-TSE (Sagittal) |
|---|---|---|---|---|
| Repetition time (ms) | 5440 | 3960 | 3980 | 600 |
| Echo time (ms) | 83 | 44 | 41 | 11 |
| Flip angle | 140 | 140 | 140 | 150 |
| Distal factor (mm) | 15% | 12% | 10% | 10% |
| Number of slices | 31 | 29 | 31 | 31 |
| Thickness ratio (mm) | 3.0 | 3.0 | 3.0 | 3.0 |
| Voxel size (mm) | 0.3x0.3x3.0 | 0.4x0.4x3.0 | 0.5x0.5x3.0 | 0.4x0.4x3.0 |
| Field of view (mm) | 145 | 140 | 145 | 145 |
| Number of excitation | 2 | 1 | 1 | 1 |
| Acquisition time | 3 min 23 sec | 3 min 35 sec | 3 min 44 sec | 3 min 39 sec |

The study population was patients with different degrees of ACL in Saudi Arabia, the Hail region. The survey sample will be 50-70 patients sent to an MRI department to assess the ACL injury over four months, from September 2021 to January 2022. A patient who was between 10 – 50 years old. Sportive patients. Patients who had their injuries while practicing sports. Male and female patients are accepted to participate in the study. This study does not include historical surgeries and treatment of ligament fibers. Obese patients over (120 kg). Patients with claustrophobic, pacemaker, and metal implants are also excluded.

**Results and Discussion**

A retrospective study was established to esteem the efficiency of new ACL imaging approaches within the Saudi population, Hail region, between Sep 2021 to Jan 2022 interval. **Table 1** demonstrates the minimum, maximum, mean, and standard deviation for the study population age, **Table 2** demonstrates the distribution of gender in this study. **Figure 1**, demonstrates A thirty-five old male with a suspected partial tear in standard PD-sagittal sequence but confirmed as a complete tear in additional two sequences (PD-sagittal oblique and DWI and ADC map-sagittal oblique).

**Table 1.** demonstrates the minimum, maximum, mean, and standard deviation for the study population age.

|  | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Age | 67 | 12 | 46 | 31.01 | 8.194 |
| Valid N (leastwise) | 67 |  |  |  |  |

**Table 2.** Demonstrate the distribution of gender in this study

|  |  | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | F | 11 | 16.4 | 16.4 | 16.4 |
|  | M | 56 | 83.6 | 83.6 | 100.0 |
|  | Total | 67 | 100.0 | 100.0 |  |

a)



b)



c)



d)
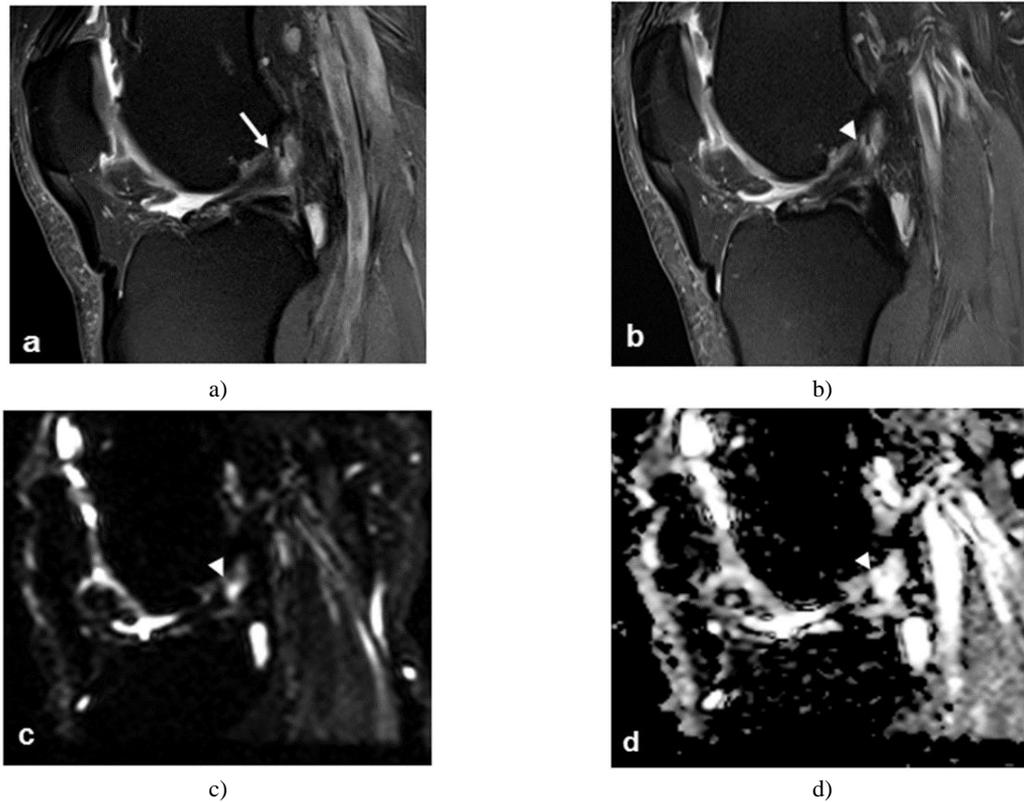
**Figure 1.** a) Standard Pd –weighted image with sagittal planning (suspected as a partial tear) intermediate signal along mid and upper segment of ACL, but still contact fibers with femoral upper aspect (white arrow). b) PD-weighted image with sagittal oblique, heterogeneity of ACL course, and unobvious continuous fiber that contacts with femoral aspect (arrowhead), suspected as a complete tear. c) DWI image (sagittal-oblique) and d) ADC mapping, high signal substance as an edematous mass (arrowheads) confirm as a complete tear.

Among the sixty-seven cases associated, an overall 43 (64.1%) exemplify abnormalities consequences after a knee injury **Table 3**.

To the best of our understanding, the anterior cruciate ligament is assisted in preserving physical activity stability properly; traumatic incidents occur most frequently to this important ligament, such as in football, falling, and basketball players. Our results demonstrate that a complete tear of the anterior cruciate ligaments is the most frequently reported Injury (34.3%), followed by a partial tear of anterior cruciate ligaments (24%), as presented in **Table 3**. Almost most the injury rife occurrence in males more than in females by approximately five to one **Table 4**. Generality ACL accidents correlate to athlete adults. **Table 5** demonstrated that aged 21 to 30 have a predominant episode with 41.8%.

**Table 3.** Demonstrate the final diagnosis for the patient with anterior cruciate ligament injuries using knee MRI sequences.

|       | ACL diagnosis | Frequency | Percent |
|-------|---------------|-----------|---------|
|       | Complete Tear | 23 | 34.3 |
|       | Normal ACL | 24 | 35.8 |
| Valid | Partial Tear | 16 | 24 |
|       | Poor definition | 4 | 5.9 |
|       | Total | 67 | 100.0 |

**Table 4.** Demonstrate the distribution of findings for the patient with anterior cruciate ligament injuries and normality according to gender.

|        |   | Complete Tear | Normal ACL | Partial Tear | Suspected Complete Tear | Suspected Normal but not clear | Suspected Normal or sprain | Suspected Partial Tear | Total |
|--------|---|---------------|------------|--------------|-------------------------|--------------------------------|----------------------------|------------------------|-------|
| Gender | F | 3 | 7 | 1 | 0 | 0 | 0 | 0 | 11 |
|        | M | 15 | 17 | 11 | 7 | 3 | 1 | 2 | 56 |
| Total  |   | 18 | 24 | 12 | 7 | 3 | 1 | 2 | 67 |

**Table 5.** Demonstrate the distribution of findings for the patient with anterior cruciate ligament injuries and normality according to age groups.

| | | Complete Tear | Normal ACL | Partial Tear | Suspected Complete Tear | Suspected Normal but not clear | Suspected Normal or sprain | Suspected Partial Tear | Total |
|---|---|---|---|---|---|---|---|---|---|
| | 10-20 | 0 | 1 | 2 | 1 | 0 | 0 | 1 | 5 |
| | 21-30 | 8 | 11 | 4 | 3 | 1 | 0 | 1 | 28 |
| Age | 31-40 | 7 | 10 | 4 | 2 | 2 | 0 | 0 | 25 |
| | 41-50 | 3 | 2 | 2 | 1 | 0 | 1 | 0 | 9 |
| Total | | 18 | 24 | 12 | 7 | 3 | 1 | 2 | 67 |

A high statistical difference is visible between approach C versus approach A and B in terms of sensitivity and specificity for detecting full-thickness ACL tears (94%) and (95%) **Table 6a**. Furthermore, good analytical diagnostic findings were apparent between approaches A and B for detecting complete tears with (79%), (84.6%) and (88%), (89.7%), respectively **Table 6a** Otherwise, approach A's sensitivity and specificity were remarkably lowest values than those other approaches with partial tears. Moreover, approach C's sensitivity and specificity in detecting partial ACL injuries were substantially distinct from those of approach B with (90%), (96%) and (80%), (91%), respectively **Table 6b**.

**Table 6.** Demonstrate the sensitivity, specificity, and accuracy of diagnosis for the patient with a) a complete ACL tear, b) a partial ACL tear, c) a poor definition of ACL normality with each approach.

| a) Demonstrate the sensitivity, specificity, and accuracy of diagnosis for the patient with a complete ACL tear with each approach | | | |
|---|---|---|---|
| | Sensitivity | Specificity | Accuracy |
| Approach (A) | 79 | 84.6 | 81.8 |
| Approach (B) | 88 | 89.7 | 85.3 |
| Approach (C) | 94 | 95 | 92 |
| b) Demonstrate the sensitivity, specificity, and accuracy of diagnosis for the patient with a partial ACL tear with each approach | | | |
| Approach (A) | 69 | 89.4 | 79.2 |
| Approach (B) | 80 | 91 | 82.3 |
| Approach(C) | 90 | 96 | 93 |
| c) Demonstrate the sensitivity, specificity, and accuracy of diagnosis for the patient with a poor definition of ACL normality with each approach. | | | |
| Approach (A) | 87.5 | 84.6 | 86 |
| Approach (B) | 100 | 100 | 100 |
| Approach(C) | 100 | 100 | 100 |

At a glance at **Table 6c**, it shows the sensitive, specific, and accurate values for the valuation of poor definition ACL according to various interpretation approaches; the whole three values concerning approach A in the detection of normative ACL were markedly smaller than those for procedures B and C. In comparison, approaches B and C did not differ significantly in accuracy, sensitivity, or specificity.

MR as non-invasive diagnostic imaging is preferable for verifying the knee's cruciate anterior ligament injuries. However, there is challenging to savvy complete or partial tear with standard knee protocol; therefore, several previous studies recommended applying sagittal oblique planning. Soliman HH concluded that sagittal and coronal oblique significantly higher accuracy in identifying ACL injuries, particularly for partial tear injuries [9]. Moreover, the prospective observational study designed by Mohammad Ghasem *et al*. [10] also evaluated the angulated technique (oblique) with coronal and sagittal planes in diagnosing anterior cruciate ruptures. Their significant findings are of apparent importance to this projection. In this present study, when we compared the sagittal oblique proton density (fat-saturated) sequence results with the results of the routine MRI (standard protocol) for anterior cruciate ligaments injuries, we found that the sagittal oblique PD (fat-saturated) additional to standard protocol (approach B) has higher sensitivity and specificity values (88%), (89.7%) with complete tear and (80%), (91%) with a partial tear, respectively **Table 6**.

Recently, Research about DWI (ADC map) is interesting because it has observant diagnostic merit. For example, there is evidence that DWI is useful in detecting vertebral compression fractures and assessing anterior cruciate ligament (ACL) lacerations [11]. Nevertheless, it demands more implementation. According to the knee's fiber bundle anatomical structure, the ligament has not containing bound water because it is rich in collagen; thus, it will appear as a low signal in the ADC map image [12]. From this perspective, we hypothesized this sequence with sagittal oblique planning. In our results, when we added the sagittal oblique with proton density (fat-saturated) sequence as a morphological and DWI (ADC mapping) sequence to the standard knee MRI sequences; the sagittal oblique PD (fat-saturated) and DWI (ADC mapping) sequences appeared significantly (94% sensitivity) and (95% specificity) values for ACL complete tear were estimated and (90%), (96%) for partial tear comparing to the standard knee sequences only (79%) and (84.6), and (69%) and (89.4%), respectively **Table 6**.

Our findings on the sensitivity and specificity of DWI and ADC map for appraising anterior cruciate ligaments injuries, notably to differentiate between various injuries, were approximately compatible with the results of Cyrille Delin *et al.* [12], were found that the ADC map sensitivity and specificity in diagnosis ligaments injury (96%) and (94%), respectively for a complete ACL tear. However, our results conflict with Park HJ *et al.* [13] study; in this previous study, a significant difference in specificity did not exist between conventional MRI and DWI (97.4%) and (86.8%), respectively. Therefore, adding the DWI did not consider.

Our study found a statistically significant difference between standard protocol and approach B and C techniques regarding the value of neat planning parallel to the morphology of the anterior cruciate ligament, and thin slice thickness (2mm) for additional sequences other than standard protocol parameters. While, the DWI with ADC map has increased the specificity value in diagnosing ACL injuries (100% in poor definition, 96% in partial, 95% incomplete). DWI and ADC mapping images have a good spatial resolution in our experimental and capacity to reveal the fibers amidst oedema and heterogeneity of tissues and segmentation pattern rather than PD (fat-saturated) in disturbing cases with a short acquisition time (1.52 min).

Limitation points to this current study. First, larger samples provide more accurate mean values, identify outliers that could cause skewing in a smaller sample, and provide a small margin of error. Second, this study does not include arthroscopy procedures because it is considered a gold standard; however, our hospital lacks this procedure; we depended only on physical examination accompanied by additional MR sequences. Third, we did not subjoin axial planning with DWI sequence and oblique planning with coronal orthogonal. Fourth, the time between an injury and an MR examination fluctuates rather than closely.

**Conclusion**

This retrospective study concluded that the value of sagittal oblique planning with proton density (fat saturated), DWI, and ADC map, was beneficial in many ACL abnormalities. In addition, our data demonstrated that DWI-correlated ADC mapping is efficacious in the work-up of patients suspected to have ACL partial or complete tears. Moreover, the time acquisition for additional sequences does not consume much time (3.56 min) for both sequences.

*Recommendations*

- Emphasizing the appropriate use of sagittal oblique planning in managing a patient with an ACL injury.
- DWI and ADC map sequence had a highly reliable diagnosis, mainly if there is a suspected difference between partial and complete tear or poor definition ACL; we recommended it be added to the standard MRI Sequence to increase the detection sensitivity of abnormalities.
- DWI with ADC map is an advanced and highly diagnostic-sensitive tool; therefore, technologists should be accurately trained to implement highly accurate diagnostic capabilities of MRI protocols.

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