Zagazig University Medical Journal
www.zumj.journals.ekb.eg
https://dx.doi.org/10.21608/zumj.2020.23219.1729 Volume 28, Issue 6, November 2022(232-241) Supplement Issue

Manuscript ID ZUMJ-2002-1729 (R1)
DOI **10.21608/zumj.2020.23219.1729**

ORIGINAL ARTICLE

Role of Diffusion Weighted Magnetic Resonance Imaging in Detection of Traumatic Knee Bone Marrow Lesions

Sarah Ali Soud[1]; Osama AbdAllah Dawoud[1]; faten fawzy mohammed2; engy fathy tantawey[2]

[1]*Radiodiagnosis/faculty of medicine/zagazig University*

[2]*radio-diagnosis/faculty of medicine/zagazig university*

Corresponding author
Sarah Ali Mohammed El Sadik , MSc student, radio-diagnosis/Al Ahrar teaching Hospital /Zagazig
E.mail : misspinkypink18@gmail.com

Submit Date 2020-02-27
Revise Date 2020-05-09
Accept Date 2020-05-16

ABSTRACT

Background: Bone marrow lesions (BMLs) are a common finding after acute bone trauma. BMLs are assessed with conventional MRI sequences. Unlike conventional MR imaging sequences, diffusion-weighted imaging depends on the random movement of water molecules. Intact bone marrow shows directional diffusion, whereas BML shows facilitated diffusion. ADC maps might add value to conventional MRI sequences in trauma imaging protocols.

Objective: To compare ADC map with conventional fat saturation imaging sequences in the detection of bone marrow lesions (BMLs) after knee trauma.

Methods: This study was carried out at Radio diagnosis Department in University Hospitals; the present study was carried on 20 patients after suffering from knee trauma. Patients underwent Conventional and diffusion MRI, the lesions were calculated in ADC maps, STIR and FS PD weighted imaging.

Results: The BMLs have been calculated in terms of the number and volume in ADC map, PD FS weighted TSE imaging and STIR. The median volumes were calculated to test the level of significance. The total median value of all knee bones collectively in ADC map was (53.4 cm^3) approximately twice the median lesion volume in STIR (20.7 cm^3) and FS PD weighted images (24.7 cm^3). The median values of the BML in ADC map of knee were statistically higher than the median value of BML in SITR and FS PD weighted TSE imaging sequences. All p-values were statistically significant.

Conclusion: Our results indicated that ADC maps are more sensitive than conventional MRI sequences as it improves the detection of small bone marrow lesions

Keywords
Diffusion Weighted imaging; MRI; Bone marrow lesions; knee.

1. INTRODUCTION

BMLs are considered a common finding after acute bone trauma [1]. Histological bone marrow lesions have been linked to trabecular micro fracture, oedema, haemorrhage, fibrosis, and necrosis [2]. The bone marrow lesion pattern represents clues which improve diagnostic precision in detection of concomitant injuries **[3]**.
Magnetic resonance imaging is non-invasive accurate diagnostic method in assessment of traumatic knee insult especially if associated soft-tissue injury is predicted. Bone marrow lesions are traditionally assessed with conventional MRI sequences such as T2-weighted fat-suppressed or short time inversion recovery (STIR) sequences, which highlight the presence of free water, displayed as regions of ill-defined hyper-intensity in the subchondral bone. There are no specific histopathological changes in bone marrow lesions actually present to explain the MR signal, but it has been suggested that the T2 hyper-intensity results from increased blood flow or trabecular micro-fractures within the lesions [4].Spectral fat saturation is sensitive to magnetic field non uniformity which can be caused by coil in homogeneity or patient inherent artifact sources, such as implants [5]. Inversion-recovery sequences

with selective suppression of fat signal can be used where spectral fat saturation is challenging **[6]**.

Unlike standard conventional MR imaging sequences, in diffusion-weighted imaging the signal depends on the random movement of water molecules **[7]**. These functional diffusion data can be displayed quantitatively on ADC maps were ADC values are calculated to differentiate lesions with facilitated diffusibility from lesions with restrictive diffusibility. The ADC of normal epiphyseal bone marrow in the knee is slightly different in yellow marrow ($0.1{\times}10^{-3}$Mm^2/sec) than in red bone marrow ($0.2{\times}10^{-3}$Mm^2/sec), however both types of marrow represents restricted pattern of diffusion. The restricted pattern in normal bone marrow was attributed to the act that trabicular meshwork represents a natural barrier that prevents free diffusion of water molecules within the bone epiphyses. Unlike normal bone marrow, traumatic bone marrow lesion showed areas of hyper intensities representing facilitated diffusion and there ADC values are around ($0.8{\times}10^{-3}$Mm^2/sec) [7].

Because of short acquisition times, ADC maps might add value in the usually used conventional MRI sequences in trauma knee imaging protocols, improving detection of small bone marrow and detected more sizable lesions [7].

Aim of the study is to compare single-shot echo-planar diffusion-weighted imaging–derived apparent diffusion coefficient (ADC) maps with conventional fat saturation imaging sequences in the detection of bone marrow lesions (BMLs) after knee trauma.

PATIENTS AND METHODS

This study included 20 patients, referred from Emergency and Orthopedic Departments in University Hospital to Radiology Departments University Hospital, during six months period after obtaining institutional board review from our hospital and informed consent from patients before the study. The studied group included 8 females and 12 males. Their ages ranged between 16-59 years.

The study was approved by research ethical committee of faculty of medicine, Zagazig University .the study was done according to the code of ethics of the world medical association (Declaration of Helsinki) or studies involving humans.

The study design was prospective; with inclusion criteria of any patient subjected to knee trauma within 90 days from traumatic incidence, all age groups were included. Exclusion criteria were patients with implanted pacemaker and other cardiological devices incompatible with MRI, patients with ocular implants, patients with aneurysmal clips, patients with metallic implants in the knee joint area (checked by complementary X-ray examination).The time frame was carried out through a period of 6 monthes, from September 2018 to march 2019.

All patients were subjected to full clinical history; Personal history (name, age, gender), present history including the main clinical presentation of these patients, clinical examination; patients assessed by the orthopedic surgeon then redirected to the radiology unit, radiological assessment; all patients had MR imaging of the affected knee joints on a high field-strength scanners.

MRI was performed using Philips scanners Achieva (1.5 T) with a dedicated knee coil in all cases. All patient underwent both conventional and diffusion MRI sequences.The patients were positioned supine with the affected knee extended in the knee coil and rested over knee pad.

The MRI study included sagittal T1WIs, sagittal T2 WIs. axial T2WIs, coronal STIR, sagittal Fat suppression (FS) proton density-weighted (PDw) turbo spine echo (TSE) imaging as well as sagittal Single-Shot Echo-Planar DWI–derived ADC mapping pulse sequences.

The parameters applied were slice thickness 4 mm slice gap 1.6-2.4 mm, matrix 256/192 or 512/224, field of view ranged from 12 to 16 cm, in obese patients the field of view was (18-20 cm).The average duration time of the examination was about 30 minutes.

Cases were revised and interpreted by the radiologist using both conventional and diffusion images. All detected bone marrow lesions were counted in STIR, fat suppression (FS) proton density weighted (PDW) turbo spin echo (TSE) and ADC map. All detected BMLs were subjected to volumetric measurement in each bone separately using 3D slicer program by tracing the whole area of the lesion in each section using the segment editor and then applying segment statistics where the volume of the traced lesion is calculated in cm^3.

ADC values were measured in intact bone marrow, major bone marrow lesions and fractured areas.

Data were statistically described in terms of frequencies (number of cases) and percentage when appropriate .Data were checked, entered and analyzed by using SPSS version 20. Data were presented as follow: mean for quantitative variables (age, ADC values).Number and percentage for categorical variables (symptoms, site of BMLs, associated soft tissue injury, different BML patterns).

Kruskal-Wallis's test was applied to calculate the level of significance with threshold of significance fixed at 0.05 level (P-value).

RESULTS

The study group was about 50 knee trauma patients admitted to the orthopedic department during the time frame provided, however after reviewing the MRI images; 15 patients were excluded due to technical errors and distorted diffusion derived ADC map images, 10 patients had osteoarthritic bone marrow changes due to aging, they were excluded to avoid over lapping calculation between the osteoarthritic changes in bone marrow and traumatic bone marrow lesion, the remaining 5 patients' images showed no bone marrow lesion though they were subjected to knee trauma, and as our main concern in this study was to calculate the volume of traumatic bone marrow lesions those patients were excluded.

This study included **20** symptomatic patients with history of acute trauma, 12 males and 8 females. The mean age of the studied group was 29years ±9.7 **(Table.1).** It was clear that knee trauma was more common in males than females and the peak incidence of presentation lies in the third decade followed by the second decade then the fifth decade **(table.2).** These patients were presented with different clinical manifestations mainly knee pain, instability, swelling, locking and limitation of movement. The most common clinical presentation as shown in the **(Table.3)** is pain (100%) followed by limitation of movement (60%) and swelling (35%). More than one of the previously mention presentation was present in every patients complaint **.**The patients presented usually with BMLs in one or more of the following sites: both femoral condyles, tibial plateau and patella. The lateral compartment of the knee including in the lateral femoral condyle and lateral aspect of tibial plateau was the most affected site **(Table 4).**The mean ADC value measured in the BMLs among the studied group, and the range of calculated ADC values from the least ADC value detected in BML to the highest ADC values. ADC values of normal epiphyseal bone marrow in the knee was measured as well, the ADC values of yellow marrow and red marrow was approximately corresponding to $(0.1 \times 10^{-3}\ mm^2/sec)$ and$(0.2 \times 10^{-3}\ mm^2/sec)$ respectively(**Table.5**).In the studied group 3 BML patterns were recognized. The most common type of BML was pivot-shift injury 30% of the cases followed by hyperextension pattern 20% and in the third place came the dashboard pattern with 15% of the cases **(Table.6)**.

In the study we detected 2 femoral condyle fractures and 3 tibial plateau fractures there were no patellar fractures found in the studied group. ADC values were measured in the fractured areas the values were ranging from $(1.8 - 2.2 \times 10^{-3} mm^2/sec)$ **(Table 7 & 8).**The median values of the BML in ADC map of femur bone was statistically higher than the median value of BML in SITR and FS PD weighted TSE imaging sequences (P-value <0.005**, p-value<0.01** respectively).The median value of the BML in ADC map of the tibia bone was statistically significantly higher than the median value of BML in SITR sequence (P-values <0.05*). In addition, the median value of the BML in ADC map in patella was statistically higher than the median value of the BML in both SITR and FS PD weighted TSE imaging sequences (p-value <0.001*** and p-value <0.001*** respectively).The total median value of all knee bones collectively in ADC map is ($53.4\ cm^3$) approximately twice the median lesion volume in STIR ($20.7\ cm^3$) and FS PD weighted TSE images ($24.7\ cm^3$).p-value was calculated confirming high degree of significance (**Table 9)**.

Case 1: A 19 years old male patient admitted to emergency department with history of twisting his knee. The patient was complaining of instability on weight bearing, severe pain and swelling. The patient's MRI examination revealed the following.

Figure A: sagittal T2 weighted image showing minimal joint effusion and complete ACL tear.

Figure B: coronal STIR image showing ill-defined hyperintense areas of traumatic bone marrow lesion at the lateral aspect of tibial plateau.

Figure C: Sagittal FS PD weighted TSE image showing ill-defined hyperintense bone marrow lesion at the anterior aspect of lateral femoral condyl and lateral aspect of tibial plateau as well, representing pivot shit BML pattern.

Figure D: Showing Sagittal ADC map with the BMLs detected more sizable than the same lesions in the sagittal FS PD weighted TSE image.

Case 2: A 47-year- old male had history of motor cycle accident. He was suffering from severe pain and difficulty in walking.

Fig. A: Sagittal T1weighted Images showing PCL avulsion fracture grade III, with companion traumatic bone marrow lesion at the posterior aspect of tibial plateau.

Fig. B and C: Sagittal ADC Map and Sagittal FS PD Weighted TSE Image showing area of traumatic bone marrow lesion at the posterior aspect of tibial plateau. The lesion is seen more sizable in the ADC map image (the lesions are traced in white to emphasis the difference in size between the two images).

Table (1): Sociodemographic data among the studied group including mean age and gender distribution:

Parameters	Patients	
	Mean ±	SD
Age	29 ±	9.7
Gender	No.	%
Male	12	60.0
Female	8	40.0

Table (2): Age groups and gender classification of included patients in this study:

Age	Male	Female	No. Of patients	Percent %
10 < 20	4	2	6	30%
20 < 30	6	2	8	40%
30 < 40	2	0	2	10%
40 < 50	0	3	3	15%
50 < 60	0	1	1	5%
Total	12	8	20	100%

Table (3): The main clinical presentation of the studied group:

Clinical presentation	No. of patients	Percent%
1. Pain	20	100%
2. Limitation of movement	12	60%
3. Swelling	7	35%
4. Instability	5	25%
5. Locking	3	15%

Table (4): representing different sites of BMLs observed in the studied group.

Site of lesion	No. of patients	Percentage %
1. Lateral femoral condyle	11	55%
2. Medial femoral condyle	2	10%
3. Posterior aspect of patella	1	5%
4. Anterior aspect of tibia	3	15%
5. Lateral aspect of tibial plateau	11	55%
6. Medial aspect of tibial plateau	4	20%

Table (5) shows the mean ADC value measured in BMLs among the studied group:

Item	Mean ± SD	Range
Value	$1.27 \pm 0.0921 \times 10^{-3}$ mm^2/sec	$0.7\text{-}1.4 \times 10^{-3}$ $mm^2/sec.$

Table (6): representing the pattern of BML in the studied group.

Pattern of BML	frequency	Percentage
1-Pivot shift pattern	6	30%
2-Dashboard pattern	3	15%
3-Hyperextention pattern	4	20%
4-Non specific pattern	7	35%

Table (7): showing the no. of cases with fractured bone included in the study.

Fractured bones	Femur	Tibia	Patella	Total
Frequency	2	3	0	5
percentage	10%	15%	0%	15%

Table (8): showing the mean ADC value detected at fractured bones

Mean ADC value at the site of fracture	Range
2×10^{-3} mm^2/sec	$1.8 – 2.2 \times 10^{-3}$mm^2/sec

Table (9): Median volumes of BMLs calculated in different STIR, FS PD weighted TSE imaging and ADC map among the studies group of patients:

MRI sequences	ADC map		STIR		FS PD weighted TSE imaging		KRUSKAL-WALLIS TEST	P-VALUES
Vol. of BML	N=20		N=20		N=20			
	Median	cm^3	Median	cm^3	Median	cm^3		
Vol. of BML in femur	19.3		3.7		5.7		25.8	0.000***
Vol. of BML in tibia	32.0		11.6		19.0		6.0	0.05*
Vol. of BML Patella	2.1		0.00		0.00		34.5	0.000***
total	53.4		20.7		24.7		24.3	0.000***

*means (P-value<0.5=significant results)

*** means (p-value<0.0001=Very high degree of significance)

Case presentation:

Figure A: sagittal T2 weighted image showing minimal joint effusion and complete ACL tear.

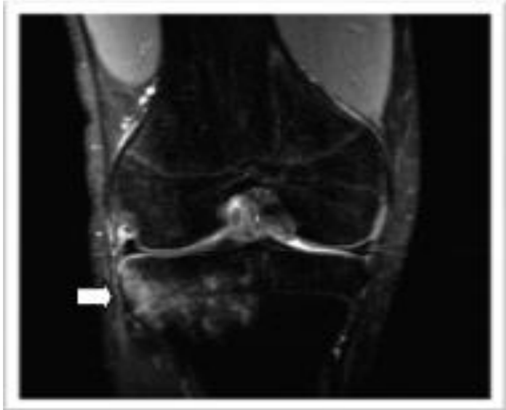

Figure B: coronal STIR image showing ill-defined hyperintense areas of traumatic bone marrow lesion at the lateral aspect of tibial plateau.

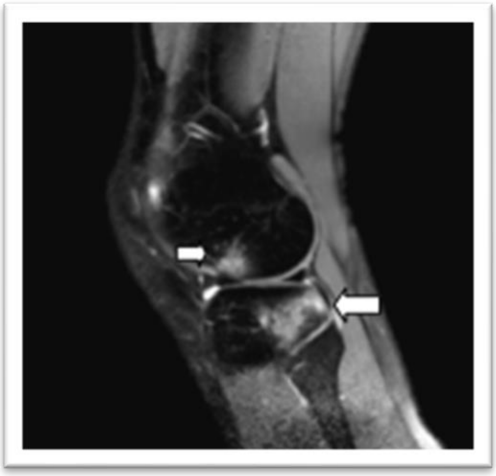

Figure C: Sagittal FS PD weighted TSE image showing ill-defined hyperintense bone marrow lesion at the anterior aspect of lateral femoral condyl and lateral aspect of tibial plateau as well, representing pivot shit BML pattern.

Figure D: Showing Sagittal ADC map with the BMLs detected more sizable than the same lesions in the sagittal FS PD weighted TSE image.

Case 2

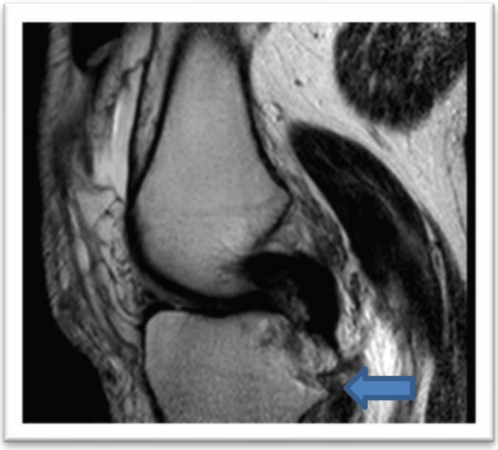

Figure A: Sagittal T1weighted Images showing PCL avulsion fracture grade III with companion traumatic bone marrow lesion at the posterior aspect of tibial plateau.

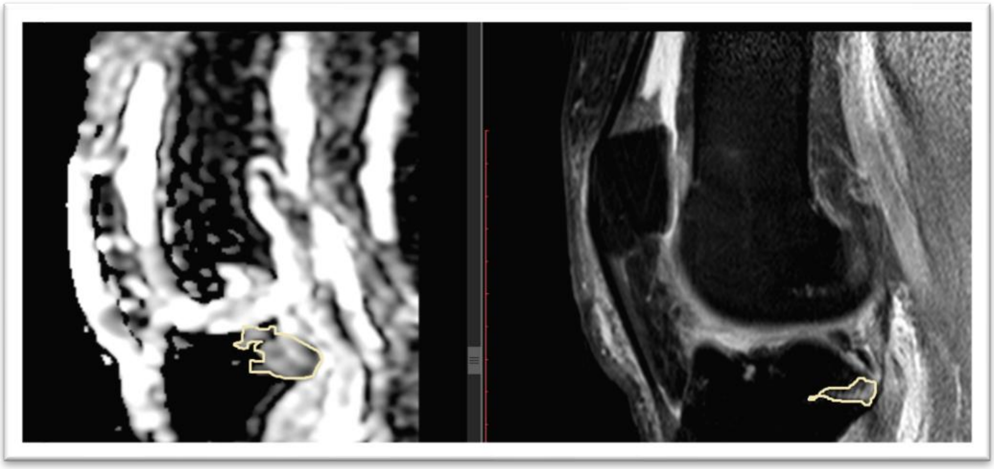

Fig. B and C: Sagittal ADC Map and Sagittal FS PD Weighted TSE Image showing area of traumatic bone marrow lesion at the posterior aspect of tibial plateau. The lesion is seen more sizable in the ADC map image (the lesions are traced in white to emphasis the difference in size between the two images).

DISCUSSION

The knee joint is the most frequently injured joint of the human body. The knee injuries affect both the general population and the athletic population of different age groups. Traumatic injuries of the knee joint, which are often caused by sports activities, constitute a large proportion of musculoskeletal trauma encountered in the emergency department **[8]**.

The initial evaluation of knee injuries usually consists of taking the clinical history and performing a physical examination**.** Although physical examination may aid in establishing the diagnosis, its accuracy in the acute stage has been questioned and that accuracy is influenced by many factors. Moreover, it has been well recognized that thorough physical examination of a recently injured knee with acute hemarthrosis often is difficult because of swelling, pain, and guarding **[9]**.

MRI has become the most commonly used imaging modality in the evaluation of the knee joint due to its superb soft tissue contrast and multiplanar capabilities. MRI makes it ideal for evaluating suspected injuries of the muscles, ligaments, menisci, tendons, and articular cartilage, as well as in the evaluation of bone contusions, occult fractures, and fluid collections about the knee **[10]**.

The combination of both MRI and good physical examination can provide an accurate assessment of the entire knee and thus guide appropriate therapeutic intervention **[11].**

The purpose of this study is to highlight the accuracy of DWI-ADC Derived single shot echo planner imaging sequence in detecting traumatic BMLs and its advantage over the conventional fat suppressing sequences particularly FS PD weighted TSE imaging and STIR.

Our study included 20 patients, their age ranged between 15 and 60 years old, mean age in the studied group was approximately 29 ± 9.7 years.

All patients included in the study were subjected to thorough history taking. The most presenting symptom was pain in almost 100% of the patient, which leads to the conclusion that pain is the main presenting symptom following trauma as stated in **Hutchens et al [12]**. Pain was found among different age groups with no gender predilection and for different causes.

Seventeen patients were complaining of pain and there imaging studies showed injuries in ligament, menisci and even fractured bones. 3 patients complaining of pain there imaging studies showed only BMLs with no companion soft tissue lesions. This leads us to the conclusion that BMLs are a pain generator in most of the post traumatic cases as stated by **Starr et al [13]**.

Bone marrow lesions have been a topic of increasing interest in the literature in recent years. BMLs are becoming recognized not only as a considerable pain generator, but also as an entity which is, in some cases, significantly linked to the worsening of patient prognosis **[13]**.

Different patterns of BMLs have been mentioned in literature; each type is occurred due to certain mechanism of trauma and associated with certain injury of the knee ligaments. Recognition of these patterns may help assess the full extent of knee injury. A comprehensive classification system based on mechanisms of injury and the pattern of BML would be useful for the understanding of the causative mechanism in a given case to improve detection of the complete assemblage of injuries as well as to help predict both immediate and delayed instability and need for surgery **[14]**.

Bone marrow lesions around the knee are a common magnetic resonance imaging finding. BML describes an alteration of bone marrow signal intensity, with high signal on fluid-sensitive sequences [T2/proton density with fat suppression and short tau inversion recovery (STIR)] with or without low T1WI signal **[15]**.

Unlike conventional MR sequences, the diffusion sequence depends on the random motion of water molecules which can be displayed quantitively on apparent diffusion coefficient ADC maps **Klengel et al [7]**.

Bone marrow lesions were detected at different sites of the knee bone including femoral condyles, tibial plateau and patella. The prevalence of traumatic bone marrow lesion at the lateral femoral condyle was 55%, the results of our study was discordant with **Bohndorf et al [16]** which stated that the prevalence of traumatic bone marrow lesion at the lateral femoral condyle was 26.3% only. Considering the lateral aspect of tibial plateau the prevlance in our study was 55% which was slightly different from the pravelance of lesion at the same area with percentage of 43.5% as in **Bohndorf et al [16]** study. The prevlance of both patellar region and medial femoral condyle were considerably concordant in both studies with values of 5% to the patellar region in our study in comparison to 5% of **Bohndorf et al [16]**, and 20% prevlance of BML at the medial femoral condyle in our study in comparison to 15 % prevlance in **Bohndorf et al [16].** To sum up, the least affected regions with tramatic bone marrow lesions were the patella and the medial femoral condyle in both studies.

In our study both normal areas of bone marrow and areas with BMLs have been subjected to ADC value estimation. The estimated ADC value of the normal bone marrow in all cases the values was approximately (0.1- $0.2 \times 10^{-3)}$ representing areas of anisotropic diffusing the results was consistent with the results of **Klengel et al [7]** and **Ward et al [17]**.

In areas of abundant red marrow ADC value was estimated giving a slightly higher values than yellow marrow (0.2-0.3×10^{-3}), yet still representing clearly anisotropic diffusion, which represents almost the values depicted in **Klengel et al [7]** and **Ward et al [17]** studies.

In our study areas of bone fractures showed higher signal intensity than surrounding bone marrow lesion in ADC map, and revealed higher ADC values ranging from 1.8-2.2×10^{-3} mm^2/sec with mean ADC value 2×10^{-3} mm^2/sec. the results of our study was concordant with **Biffar et al [18]** which stated that the benign fracture in vertebral bone showed ADC range 1-2×10^{-3} mm^2/sec.

Traumatic bone marrow lesion patterns have been interpreted and documented in our study. The pattern with the highest frequency was the pivote-shift pattern in 30% of the cases. The previously mention result was concordant with **Sahoo et al [19]** considering the pivot-shift pattern, as it was the most commonly found bone marrow pattern. However the results contradicted in the frequency of hyperextention BML pattern and dash board patterns. Unfortunately no cases with clip injury and lateral patellar dislocation patterns were included in our study to compare the results of both regarding those types.

Considering the associated ligamentous injury in the studied group, the most frequently discovered ligament was the ACL 50 % of the cases followed by the PCL and LCL both were affected in 15 % of the cases and MCL was the least affected ligament with 5% only. Our results were concordant with **Rani [20]** considering that the ACL was the most affected ligament in cases of trauma to the knee joint.

Significance between the number of detected lesions in ADC map and PD FS weighted TSE sequences (P-value <0.001).however the contradiction in both studies could be attributed to the difference in sample size.

Areas with BMLs on ADC map represented by areas of hyper intensity, ADC values were estimated within a range of 25mm^2 to 75 mm^2 ROI they gave values of (0.7-1.4 × 10^{-3}) and mean ADC value of (1.27 ± 0.09210×$^{-3}$ mm^2/sec).The results are concordant with that of **Klengel et al [7]** study which stated that the areas of BML ADC values ranged from (0.67-1.45×10^{-3}).In comparison to ADC values of normal bone marrow all the values measured in BMLs represented facilitated diffusion.

Baur et al [21] stated that mean ADC value of BMLs is approximately (1.6 × 10^{-3} mm^2/sec), which is slightly higher than the mean calculated in our study however still both mean values represented facilitated diffusion.

All patients included in the study had joint effusion except for one case suffered from hemarthrosis and 100% of the patient suffering from ligament injury suffered severe degree of joint effusion, the previously mentioned results stats strong correlation between joint effusion and ligament injury as mentioned by **Vogl et al [22]**.

In our results median BML volumes were calculated. The median values of the BML in ADC map of femur bone was statistically higher than the median value of BML in SITR and FS PD weighted TSE imaging sequences (P-value <0.005**, p-value<0.01** respectively).The median value of the BML in ADC map of the tibia bone was statistically significantly higher than the median value of BML in SITR sequence (P-values <0.05*). In addition, the median value of the BML in ADC map in patella was statistically higher than the median value of the BML in both SITR and FS PD weighted TSE imaging sequences (p-value <0.001*** and p-value <0.001*** respectively).

The total median value of all knee bones collectively in ADC map is (53.4 cm^3) approximately more than twice the median lesion volume in STIR (20.7 cm^3) and FS PD weighted TSE images (24.7 cm^3) The median of BMLs of all bones collectively was approximately 53.4 cm^3 in ADC map, while in STIR and FS PD weighted TSE images the values were 20.7 cm^3 and 24.7 cm^3 respectively (P-value<0.05). The previously mentioned values lead us to the conclusion that the median value of BML lesion volume in ADC map exceeded twice the median volume of BML lesion in STIR and FS PD weighted TSE images (p-value=0.000***).

The previously stated results shows great resemblance to the results of **Klengal et al [7]** study which mentioned that the median value of BMLs of all the joint bones collectively is approximately 81 cm^3 in ADC map in comparison to 39 cm^3 (P<0.001).

Limitations of the study: First, the studied population was small due to refusal of some patients to use their studies for research work purposes.

Second, DWI in musculoskeletal imaging was limited by technical problems with regard to motion artifacts.

Third, some patients were suffering multiple traumatic injuries and couldn't stand the long examination time.

Fourth, some patients suffered severe limitation in joint movement and couldn't extend the knee in the knee coil.

In conclusion, ADC showed advantage over FS PD weighted TSE sequence and STIR in terms of number and volume of detected traumatic BMLs.

Recommendation, adding DWI-Derived ADC map to the conventional knee protocol is valuable, as it helps in detecting subtle traumatic bone marrow lesions.

REFERENCES

1 Roemer FW, Frobell R, Hunter DJ, Crema MD, Fischer W, Bohndorf K, et al. MRI-detected subchondral bone marrow signal alterations of the knee joint: terminology, imaging appearance, relevance and radiological differential diagnosis. Osteoarthr Cartil. 2009;17(9):1115–31.

2 Rangger C, Kathrein A, Freund MC, Klestil T, Kreczy A. Bone bruise of the knee Histology and cryosections in 5 cases. Acta Orthop Scand. 1998;69(3):291–4.

3 Sanders TG, Medynski MA, Feller JF, Lawhorn KW. Bone Contusion Patterns of the Knee at MR Imaging: Footprint of the Mechanism of Injury. RadioGraphics. 2000;(20):135–51.

4 Saadat E, Jobke B, Chu B, Lu Y, Cheng J, Li X, et al. Diagnostic performance of in vivo 3-T MRI for articular cartilage abnormalities in human osteoarthritic knees using histology as standard of reference. Eur Radiol. 2008;18(10):2292–302.

5 Delfaut EM, Beltran J, Johnson G, Rousseau J, Marchandise X, Cotten A. Fat suppression in MR imaging: techniques and pitfalls. Radiogr A Rev Publ Radiol Soc North Am Inc. 1999;19(2):373–82.

6 Bredella MA, Tirman PFJ, Peterfy CG, Zarlingo M, Feller JF, Bost FW, et al. Accuracy of T2-weighted fast spin-echo MR imaging with fat

saturation in detecting cartilage defects in the knee: Comparison with arthroscopy in 130 patients. In: American Journal of Roentgenology. 1999; 1073–80.
7. Klengel A, Stumpp P, Klengel S, Böttger I, Rönisch N, Kahn T.Detection of Traumatic Bone Marrow Lesions after Knee Trauma: Comparison of ADC Maps Derived from Diffusion-weighted Imaging with Standard Fat-saturated Proton Density–weighted Turbo Spin-Echo Sequences. Radiology 2017;283(2):469–77.
8. Clemente FR, Fabrizio PA, Shumaker M. SHORT COMMUNICATION A Novel Approach to the Dissection of the Human Knee. 2009;(46):41–6.
9. Scholten RJ, Opstelten W, van der Plas CG, Bijl D, Deville WL, Bouter LM. Accuracy of physical diagnostic tests for assessing ruptures of the anterior cruciate ligament: a meta-analysis. J Fam Pract. 2003;52(9):689–694.
10. Oei E.H.G. Ginai A.Z. Hunink M.G.M. MRI for traumatic knee injury – a review. Semin Ultrasound CT MRI. 2007; 28: 141-157
11. Patel, N.K., Bucknill, A., Ahearne, D. et al. Early magnetic resonance imaging in acute knee injury: a cost analysis. Knee Surg Sports Traumatol Arthrosc 2012; 20, 1152–1158.
12. Calmbach W, Hutchens M. Evaluation of Patients Presenting with Knee Pain: Part II. Differential Diagnosis. Am Fam Physician. 2003;68(5):917–22.
13. A. M. Starr, M. A. Wessely, U. Albastaki, C. Pierre-Jerome & N. W. Kettner (2008) Bone Marrow Edema: Pathophysiology, Differential Diagnosis, and Imaging, Acta Radiologica, 49:7, 771-786
14. Hayes CW, Brigido MK, Jamadar D a, Propeck T. Mechanism-based pattern approach to classification of complex injuries of the knee depicted at MR imaging. Radiographics. 2000;(20):121–34.
15. Kon E, Ronga M, Filardo G, Farr J, Madry H, Milano G, et al. Bone marrow lesions and subchondral bone pathology of the knee. Knee Surgery, Sport Traumatol Arthrosc. 2016;24(6):1797–814.
16. Roemer FW, Bohndorf K. Long-term osseous sequelae after acute trauma of the knee joint evaluated by MRI. Skeletal Radiol. 2002;31(11):615–23.
17. Ward R, Caruthers S, Yablon C, Blake M, DiMasi M, Eustace S. Analysis of diffusion changes in posttraumatic bone marrow using navigator-corrected diffusion gradients. Am J Roentgenol. 2000;174(3):731–4.
18. Dietrich O, Biffar A, Baur Melnyk A, Reiser MF. Technical aspects of MR diffusion imaging of the body. Eur J Radiol 2010; 76(3):314-22.
19. Sahoo K, Garg A, Saha P, Dodia JV, Raj VR, Bhairagond SJ. Study of imaging pattern in bone marrow oedema in MRI in recent knee injuries and its correlation with type of knee injury. J Clin Diagnostic Res. 2016;10(4):06-11.
20. Rani BS. Mri Study of Types and Incidence of Internal Derangements of Traumatic Knee Joint. J Evid Based Med Healthc. 2017;3(99):5420–6.
21. Baur A, Dietrich O, Reiser M. Diffusion-weighted imaging of bone marrow: Current status. Eur Radiol. 2003;13(7):1699–708.
22. Pezeshki S, Vogl TJ, Pezeshki MZ, Daghighi MH, Pourisa M. Association of the type of trauma, occurrence of bone bruise, fracture and joint effusion with the injury to the menisci and ligaments in MRI of knee trauma. Muscles Ligaments Tendons J. 2016;6(1):161–166.

How to cite
Soud, S., Dawoud, O., mohammed, F., tantawey, E. Role of Diffusion Weighted Magnetic Resonance Imaging in Detection of Traumatic Knee Bone Marrow Lesions. Zagazig University Medical Journal, 2022; (232-241): -. doi: 10.21608/zumj.2020.23219.1729