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Ultrasound Assessment of Muscle Injury Associated with Closed Limb Fracture

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Abstract

Background: Muscle injuries are extremely common and may have a profound effect on the individual presenting with them. Determination of the severity of injury to the soft tissues is an important component of patient assessment and affects management of closed fractures.

Aim of Study: To assess muscle injury associated with upper and lower closed limb fracture using ultrasound, and to develop ultrasound classification criteria for muscle injury.

Patients and Methods: This study is a prospective observational study, was conducted on 30 patients with closed limb fracture and muscle injury at Diagnostic Radiology Department, Ain Shams Hospitals, through of 3 months.

Result: The mean size of muscle hematoma was 25.16± 6.99mm with range from 15mm to 36mm. The hematoma showed a honeycombed pattern in 3 (10%) cases.

Conclusion: Ultrasonography is useful for diagnosing acute muscle injury associated with limb fracture. The ultrasound classification criteria for muscle injury can be used to predict the severity of injury and guide decision on the type of treatment. However, the criteria need to be verified on a larger sample of patients, and some sections of the proposed criteria may require a more detailed analysis.

Key Words: *Muscle injuries – Ultrasonography – Diagnosis.*

Introduction

MUSCLE injuries are increasingly common and are often caused by acute trauma, with traffic accidents and armed conflict accounting for a significant portion of injuries. The skeletal muscle contains a pool of resident stem cells, known as satellite cells are located between the plasma membrane of myofibers and the basal lamina, which are primarily responsible for muscle regeneration. In addition to the expansion of satellite cells, timely and successful muscle regeneration is dependent upon a well-regulated inflammatory cascade [1].

The complex interplay between muscle tissue and the immune system is directly responsible for the proper regeneration following soft tissue trauma. Intramuscular leukocyte populations are an essential component of healthy skeletal muscle, and these cell populations increase and change drastically following muscle injury. Such injuries are associated with local inflammation and typically heal in the following order of events: Inflammatory phase [0-7 days post-injury]; regeneration phase; and remodelling and repair phase [2].

Muscle injury associated with closed limb fracture is commonly observed in daily medical practice.

However, an early image diagnosis can reduce patient discomfort and guide the decision of whether to implement surgical or conservative treatment [3].

The muscle is a soft tissue that is most easily studied by ultrasonography. Moreover, ultrasonography has been one of the first imaging techniques available for the evaluation of muscle disease [4].

Due to advances in ultrasound technology, it offers significant advantages over other imaging techniques in assessing muscle injury. Owing to its multiplanar approach, both transversal and longitudinal, dynamic examination of muscle, excellent spatial resolution, and definition of muscle structure, ultrasonography is on the leading edge in the assessment of muscle pathology. Furthermore, it is faster, more convenient, and cheaper than magnetic resonance imaging (MRI) [5].

However, at present, muscle ultrasonography is mainly used in sports traumatology to help a physician decide whether a patient should or should not resume professional training and competition.

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The use of ultrasonography to examine limb fracture associated with muscle injury is uncommon [6].

When closed limb fracture is associated with muscle injury, it is important to assess the viability of the muscle to decide whether a surgery is required, and which area should be operated on.

The ultrasound assessment foucs on 4 characteristics of injury of muscle fibre and complications of muscle rupture, namely, muscle hematoma, vascular injury, and diameter growth rate of the muscle to develop the ultrasound classification criteria for muscle injury [7].

Aim of the work:

The study aimed to assess muscle injury associated with upper and lower closed limb fracture using ultrasound, and to develop ultrasound classification criteria for muscle injury.

Patients and Methods

This prospective observational study was conducted at Ain Shams University Hospitals on 30 patients; range from 19 to 73 years old, 18 males and 12 females in 3 months from December 2020 to February 2021. All patients have closed limb fractures; 16 have lower limb fracture and 14 have upper limb fracture with exclusion of patients with open limb fracture, muscle inflammation, infection, hernia, tumor or intrinsic injury.

Study design: Aprospective observational study.

Study setting: Diagnostic Radiology Depatment, Ain Shams Hospitals.

Study population: Thirty patients with closed limb fracture and muscle injury.

Inclusion criteria: Patients with muscle pathology related to closed limb fractures.

Exclusion criteria: Patients with open fractures. Patients with chronic lesions. Patients with muscle inflammation or infection. Patient with muscle hernia. Patient with muscle tumor. Patient with intrinsic injury.

Sample size: 30 Patients ranged from 19 to 73 years with a mean age 46.0$\pm$14.51 years; 18 males and 12 females; 16 patients have lower limb and 14 have upper limb fractures.

Study procedure:

All procedures had been carried out in accordance with ethical standards, and informed consent was obtained from all patients. This study had been performed using colour Doppler ultrasound on patients with acute muscle injury associated with closed limb fracture. A total of 30 patients with limb fracture and muscle injury had been examined with ultrasound within 24 hours after fracture and before surgery. Muscles are usually examined using a linear array high frequency transducer In our study, we will use a 7-MHz to 15-MHz compact linear array ultrasound transducer to examine muscle injury associated with closed limb fracture. We had been use color-flow Doppler ultrasound imaging, which is widely used to show the blood flow in main arterial or venous injury and to help delineate the areas of acute muscle injury by showing increased blood flow to the affected areas. First, we had been use color Doppler ultrasound to assess the 4 major characteristics of muscle injury: Muscle fibre and complications of muscle rupture, namely, muscle hematoma, main vascular injury, and diameter growth rate of the muscle. To measure the diameter growth rate of the muscle (R change). We first had been measure the maximum thickness of the muscle from the superficial to deep layer of the muscle in both the injured (Finjury) and uninjured limbs (Fconrol). Then, we had been calculate the diameter using the following equation: (Rchange) = (Finjury - Fconrol) / (Fconrol). Next, we had been comparing the results with operative or pathological findings. Last, each of the four characteristics had been given a score to represent the degree of severity. In addition, injury had been classified into 3 grades according to the ultrasound imaging: Score less than 9, equal to 9, and more than 9.

Main outcome measures: The three grades correspond to progressively increasing severity of muscle rupture or injury in patients with limb fracture.

Statistical analysis:

Data were collected and coded to facilitate data manipulation and double entered into Microsoft Access and data analysis was performed using Statistical Package of Social Science (SPSS) software version 18 in windows 7. Simple descriptive analysis in the form of numbers and percentages for qualitative data, and arithmetic means as central tendency measurement, standard deviations as measure of dispersion for quantitative parametric data. Quantitative data included in the study was first tested for normality by One-Sample Kolmogorov-Smirnov test in each study group then inferential statistic tests were selected. For qualitative data: Chi square test to compare two of more than two qualitative groups. Sensitivity and specificity test for testing a new test with ROC curve

"Receiver Operating Characteristic". The *p*-value $<$ 0.05 was considered the cut-off value for significance.

Ethical consideration: This study was reviewed by Ain Shams University, Faculty of Medicine (Research Ethical Committee). Consent was taken from all patients, all the patient had the right not to participate in the study. The study was conducted after explaining the aim of the study and was confidentally expressed to the participants.

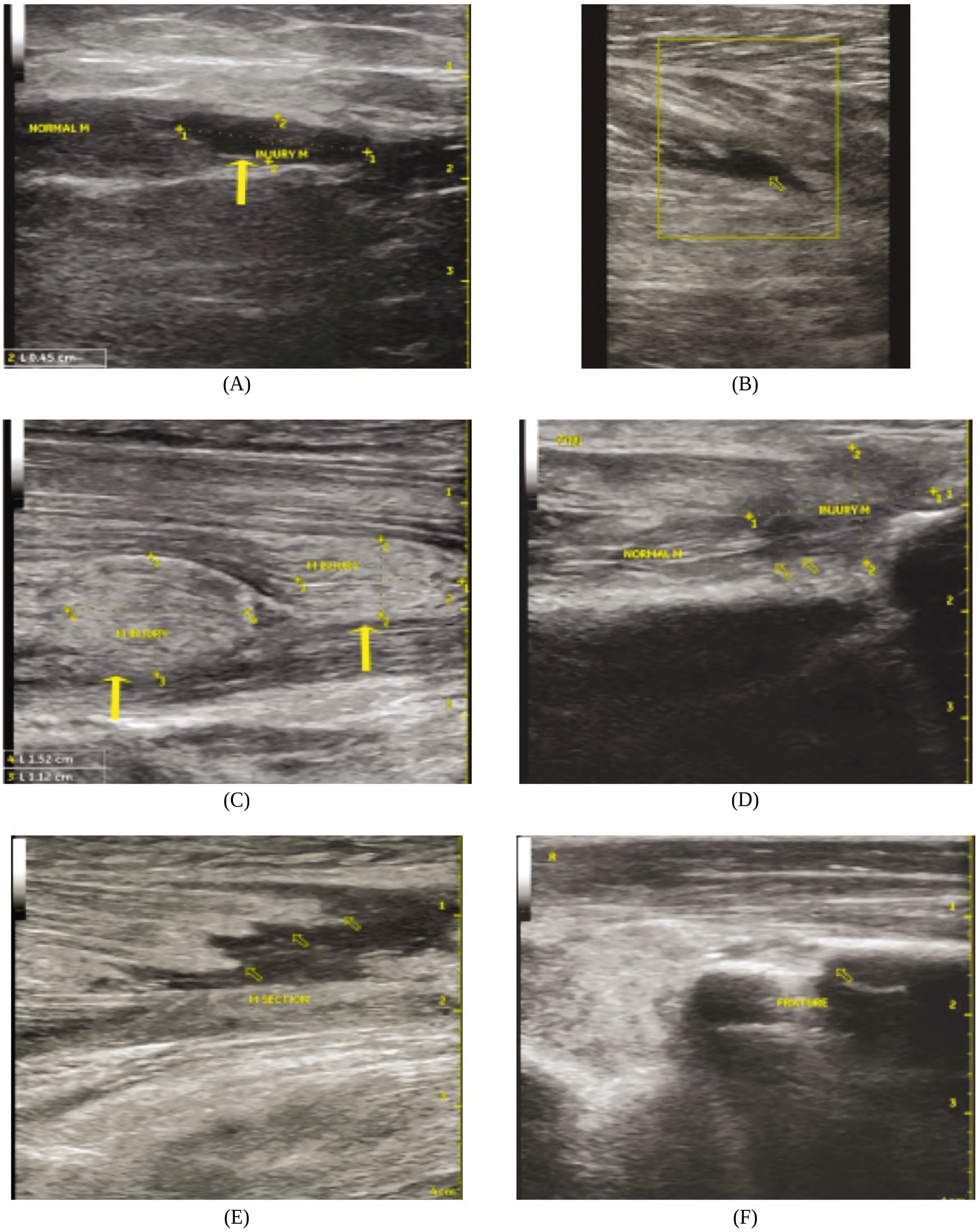

Fig. (1): 30 years old male patient came after road traffic accident, ultrasound image shows Grade I muscle rupture, but focal fibre rupture with less than 5% of the muscle involved; ultrasonography shows a hypoechoic mass within the muscle fibres (yellow arrow) (A, B). Grade II partial muscle rupture; the muscle belly forms a real mass, with focal fibre rupture with more than 5% but less than 30% of the muscles involved. Ultrasonography shows a hypoechoic mass within the muscle fibres (yellow arrow) (C, D). Grade III lesion represents focal fibre rupture with more than 30% of muscle rupture with retraction, and it also shows the bell-clapper sign, with torn muscle fragments floating in the serohematic fluid (yellow arrow) (E). Ultrasonography shows a limb fracture, fracture of the radius (yellow arrow point) (F).

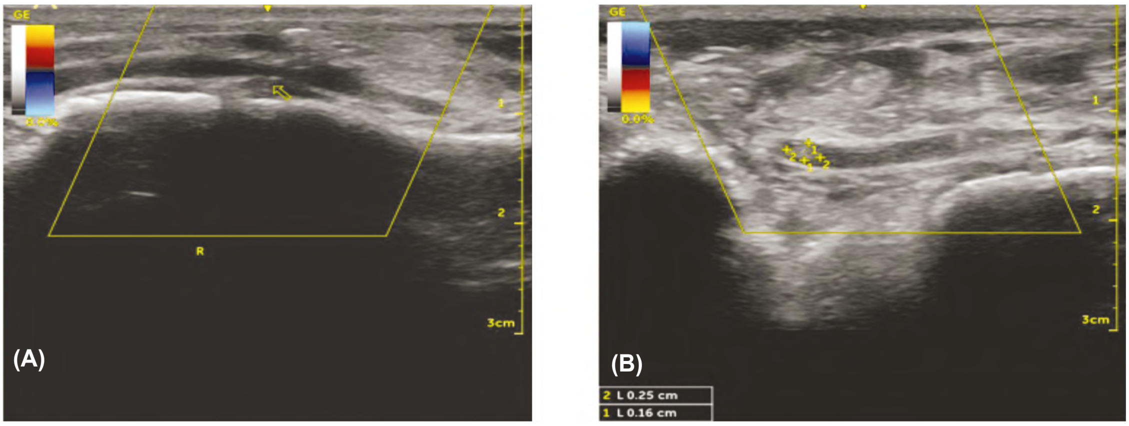

Fig. (2): 36 years old male patient came to ER after road traffic accident ultrasound image shows vascular abnormalities on ultrasonography: Decreased arterial diameter and blood flow (A); partial arterial or venous disruption, partial arterial thrombosis (B).

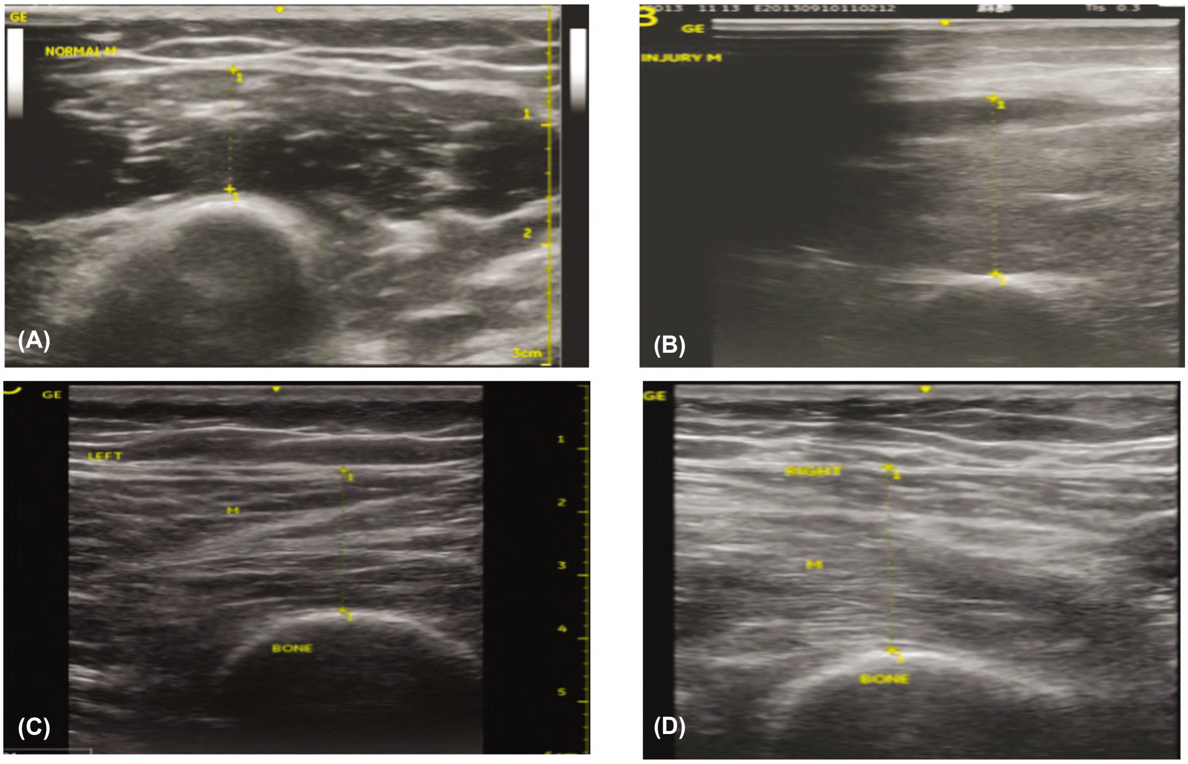

Fig. (3): 19 years old female patient came to ER after road traffic accident, the ultrasound image shows the diameter growth rate of the muscle is 170%, and this group can be classified as Grade 3; the growth rate exceeds 50% (A&B). The diameter growth rate of the muscle is 12%, and this group can be classified as Grade 2; the growth rate is between 10% and 50% (C&D).

Results

This prospective observatinal study was done among 30 patients with limb fracture and muscle injury.

As regard demographic data; age of the patients ranged from 19 to 73 years with mean age was 46.0±15.51 years. There were 18 (60%) males and 12 (40%) females with a male to female ratio of 1.5:1.

Table (1): Distribution of patients regarding demographic data.

Pre-operative demographic data	Studied patients (n=30)	
	No.	%
Age at operative intervention (years):		
Range	19.0-73.0	
Mean ± SD	46.0±15.51	
Median	45.5	
Gender:		
Male	18	60.0
Female	12	40.0

Table (2): Distribution of patients according to clinical data.

Clinical data	Studied patients (n=30)	
	No.	%
Injury type:		
Lower limb	16	53.3
Upper limb	14	46.7
Focal fibre rupture (Fig. 1):		
No	17	56.7
Yes	13	43.3
Percent of injured area:		
Range	10.0-35.0	
Mean ± SD	23.67±6.69	
Median	25.0	
10%	2	6.7
15%	3	10.0
20%	8	26.7
25%	7	23.3
30%	8	26.7
35%	2	6.7
Size of muscle hematoma:		
Range	15.0-36.0	
Mean ± SD	25.16±6.99	
Median	24.0	
Hematoma honeycombed pattern:		
No	27	90.0
Yes	3	10.0

Table (3): Distribution of patients according to US findings.

US findings	Studied patients (n=30)	
	No.	%
Vascular rupture (Fig. 2):	23	76.7
No	7	23.3
Yes		
Muscle thickness (Fig. 3):		
Range	5.0-17.0	
Mean± SD	10.60±3.98	
Median	10.5	
Increase in the diameter of muscle growth rate exceeding 50%:		
No	18	60.0
Yes (Fig. 3)	12	40.0
Increase in the area of muscle growth rate exceeding 50%:		
No	18	60.0
Yes	12	40.0

Table (4): Grading of muscle lesions according to US findings.

US findings	Studied patients (n=30)	
	No.	%
Ultrasonography of muscle fibre:		
Grade I (Fig. 1A,B)	26	86.7
Grade II (Fig. 1C,D)	3	10.0
Grade III (Fig. 1E)	1	3.3

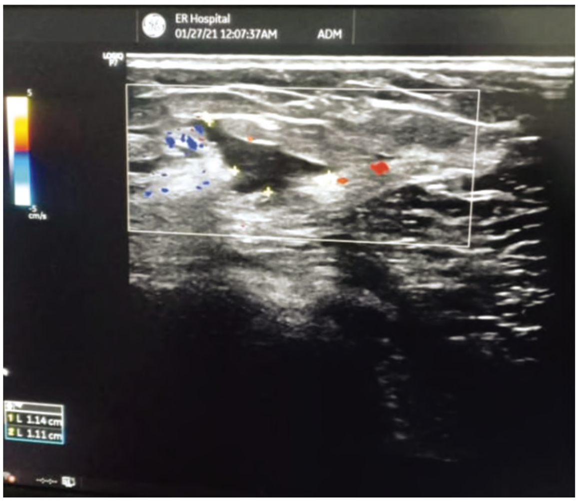

Fig. (4): 34 years old female patient came to ER after road traffic accident. Grade I muscle injury but focal fibre rupture less than 5% of the muscle involved. 2-54 years old male patient came to ER after road traffic accident.

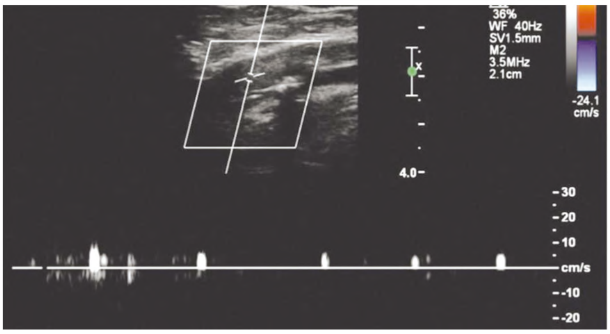

Fig. (5): 33 years old male patient came to ER after fall from height. Trasonography shows increased diameter of muscle growth.

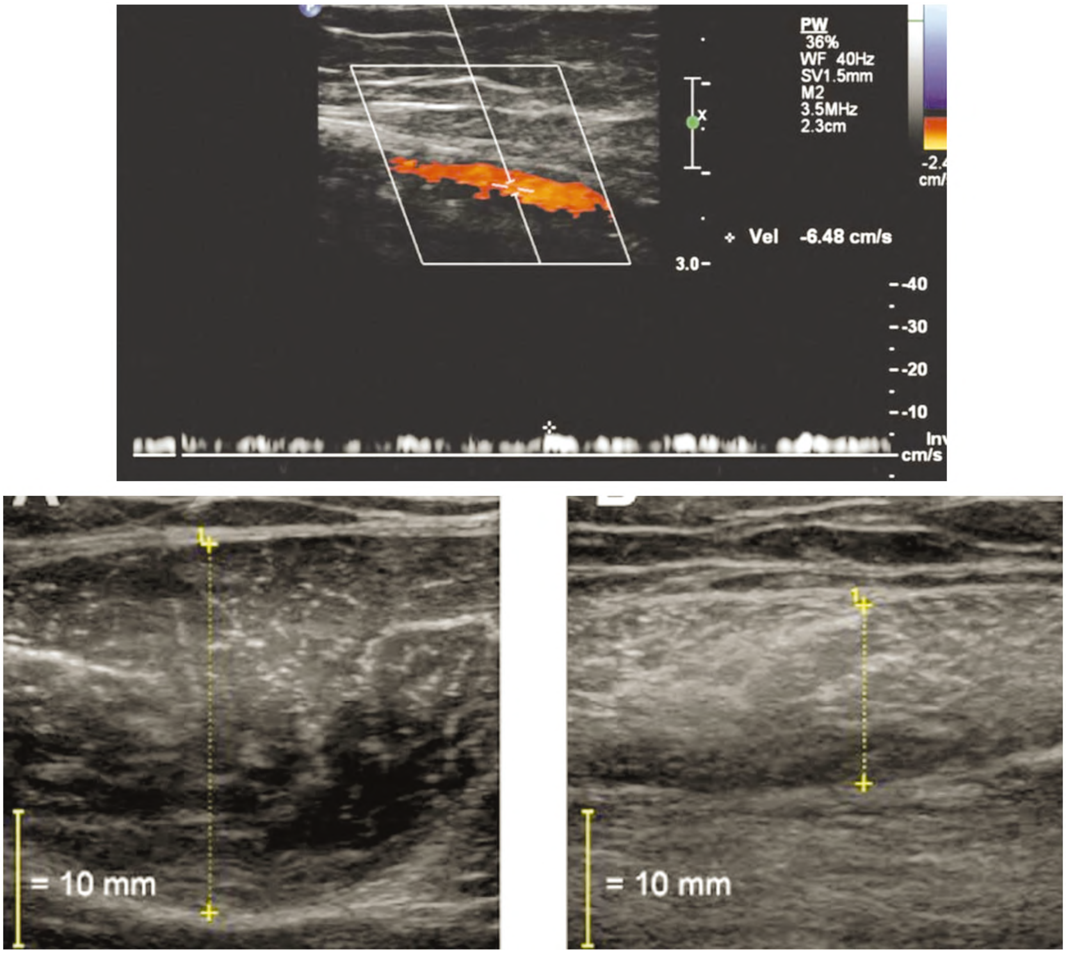

Fig. (6): 50 years old male patient came to ER ater road traaic accident, ultrasound image shows vascular abnormasities on ultrasonography; decreased arterial diameter and blood flow.

Discussion

Muscle injury associated with closed limb fracture is commonly observed in daily medical practice. Although clinical evaluation remains the mainstay of the early and accurate diagnosis of muscle injury, posttraumatic local oedema and severe pain can limit physical examination, and complete muscle tears can even be missed. However, an early image diagnosis can reduce patient discomfort and guide the decision of whether to implement surgical or conservative treatment [8].

The muscle is a soft tissue that is most easily studied by ultrasonography. Moreover, ultrasonography has been one of the first imaging techniques available for the evaluation of muscle disease. Due to advances in ultrasound technology, it offers significant advantages over other imaging techniques in assessing muscle injury. Owing to its multiplanar approach, both transversal and longitudinal, dynamic examination of muscle, excellent spatial resolution, and definition of muscle structure, ultrasonography is on the leading edge in the assessment of muscle pathology [9].

Ultrasound has become an increasingly utilized modality for evaluating soft tissue abnormalities of the musculoskeletal system. There has been a tremendous expansion of the medical literature in the past two decades paralleling this clinical use. Most instructional resources for musculoskeletal ultrasound display sonographic anatomy in neutral or other conventional positions. The clinician is often challenged with anatomic alterations that are different from familiar sonographic appearances. This is frequently a problem in conditions of trauma, post-surgical alteration, and spasticity. The changes in appearance are not only a result of alterations in normal positional relationships, but also torsional stress on the soft tissue. A systematic approach to these imaging challenges can assist with improving clarity and accuracy of interpretation [6].

Furthermore, it is faster, more convenient, and cheaper than magnetic resonance imaging (MRI). However, at present, muscle ultrasonography is mainly used in sports traumatology to help a physician decide whether a patient should or should not resume professional training and competition. The use of ultrasonography to examine limb fracture associated with muscle injury is uncommon **[10]**.

When closed limb fracture is associated with muscle injury, it is important to assess the viability of the muscle to decide whether a surgery is required, and which area should be operated on **[11]**.

The main aim of this study was to assess muscle injury associated with upper and lower closed limb fracture using ultrasound, and to develop ultrasound classification criteria for muscle injury.

This prospective observational study was conducted at Diagnostic Radiology Department, Ain Shams Hospitals. This study included thirty patients with (closed) limb fracture and muscle injury. The duration of the study was 3 months.

The main results of this study were as following:

As regard demographic data; age of the patients ranged from 19 to 73 years with mean age was 46.0±15.51 years. There were 18 (60%) males and 12 (40%) females with a male to female ratio of 1.5:1.

Muscle injuries are recognized to be among the most frequent injuries occurring in the sporting and athletic population, and they account for more than 30% of all injuries in professional soccer players. Despite their considerable frequency and impact, there is still a lack of uniformity in the categorization, description and grading of muscle injuries. For example, even though "muscle strain" is one of the terms most often used to refer to muscle injuries, it still lacks a clear definition and is used with a wide range of meanings. If we consider that the most widely used classifications and grading systems lack prognostic validity, it is easy to understand why, in the literature, there are several clinical and radiological systems, but none that is universally acknowledged accepted as the gold standard **[13]**.

For the aforementioned reasons, recent years have seen several attempts to develop comprehensive classification systems, incorporating anatomical details, clinical signs and radiographic features of muscle injuries, to investigate their prognostic value through large cohort studies, and to achieve uniformity in the current terminology referring to muscle injuries **[14]**.

The present study showed that as regard clinical data of the studied group; Sixteen (53.3%) patients had upper limb injury and the other 14 (46.7%) had lower limb injury. Focal fibre rupture was observed in 13 (43.3%) cases. The mean percent of injured area was 23.67±6.69%. in two (6.7%) cases, the injured area exceeded 30%. The mean size of muscle hematoma was 25.16±6.99mm with range from 15mm to 36mm. The hematoma showed a honeycombed pattern in 3 (10%) cases. Vascular rupture was observed in 7 (23.3%) cases.

Imaging and analysis of muscle cross-sectional area (CSA) can give understanding of the health and force production potential of a muscle. This can be particularly useful for assessment of muscles that are hard to isolate during functional testing, for example in the lower leg (knee to ankle, anatomically known as the leg), where several muscles perform the same actions. As there are no commercially readily available devices used to assess strength of specific or isolated leg muscles, anatomical muscle CSA provides the ability to infer force production of these muscles **[12]**.

There are currently limited ways to assess muscle CSA in vivo. These include magnetic resonance imaging (MRI), computed tomography, and ultrasound imaging (US). MRI has been validated and is now largely considered the "gold standard" for comparison of other imaging methods, however MRI is expensive, time consuming, and not always readily available. Computed tomography has limited availability for these purposes in the research and clinical settings as a result of the consequences of repeated radiation exposure, as well as cost. Ultrasound imaging is a relatively low-cost alternative that is becoming readily available in the research and clinical settings; however, validation of US compared to MRI is necessary for specific muscle groups.

Can be recorded in retrospective video clips (Cine-loops), that have been shown to decrease operator imaging and measurement error. As with other imaging modalities, however, US imaging is operator dependent, requires significant operator training, and has a limited field of view that requires detailed anatomical knowledge of the imaged area **[15]**.

While US measurements of several muscle groups have been validated with MRI, few studies have reported this data from any leg muscles. The specific arrangement and anatomical relationships of leg muscles present unique challenges to image acquisition and measurement. As these leg muscles are crucial during dynamic movement as well as during static posture and balance, the ability to assess these muscles' CSA accurately, reliably, and quickly is necessary [16].

US examination of a patient with suspected muscle injury should always be preceded by an accurate reporting of the patient's medical history including the mechanism of injury, symptoms, possible pain and loss of strength, and a careful clinical evaluation which may reveal the presence of masses or morphological alterations of the of anatomical part under consideration. The patient should be placed in a comfortable position to facilitate transverse and longitudinal US scanning of the muscles in question, from the proximal attachment to the distal attachment including the myotendinous junction and entheses. In some cases, a dynamic evaluation of the muscle groups in question may be useful. The entire muscle injury must be carefully studied, paying particular attention to the surrounding vascular and nervous elements. A careful study of the adjacent blood vessels is particularly important in view of the risk of venous thrombosis as a result of muscle injury [17].

The current study showed that as regard Ultrasonography findings of studied patients; vascular rupture was observed in 7 (23.3%) cases. The mean muscle thickness was 10.60±3.98mm with range from 5mm to 17mm. 12 (40%) cases showed increase in the diameter of muscle growth rate exceeding 50%. 12 (40%) cases showed an increase in the area growth rate of the muscle exceeding 50%.

As regard Grading of muscle injury using Ultrasonography; 26 (86.7%) cases had grade I, 3 (10%) cases had grade II and only one case had grade III.

Our results were supported by study of Liu et al., [3] as they used ultrasonography to assess muscle fibre rupture, muscle hematoma, main vascular injury, and diameter growth rate of the muscle. The ultrasound assessment of muscle fibre rupture directly reflects the muscle injury; muscle hematoma is one of the most important complications of muscle rupture; ultrasound assessment of main vascular injury shows blood flow in the injured muscle; and the diameter growth rate of the muscle reflects the extent of contusion and swelling. These four aspects are the most important when assessing muscle injury associated with upper and lower limb fracture.

Based on the above four characteristics of muscle injury, Liu et al., [3] used the existing clinical assessment standards, such as the mangled extremity syndrome index and the mangled extremity security score, as well as the available data on ultrasound assessment of muscle injury [18,19] to establish the ultrasound classification criteria for muscle injury. Muscle fibre, which is the first ultrasound classification criterion, is considered to be the most important one because it directly reflects the changes of the injured muscle. The other criteria B: Complication of muscle rupture (muscle hematoma); C: Main vascular injury; D: Diameter growth rate of the muscle) score the same number of points because, in our opinion, they equally contribute to early muscle injury associated with limb fracture. The total score in the classification criteria is 14 points, and the patients may gain a score from 4 to 14 points. Depending on the score achieved by a patient, a different treatment is administered. Eleven patients with scores ranging from 4 to 8 received conservative treatment; 9 patients with scores ranging from 10 to 14 received operative treatment; and 10 patients with scores equal to 9 received either conservative or operative. Thus, patients with a score of less than 9 points may have muscle injury that is not severe, and surgical treatment should be applied in patients scoring greater than 9 points (fasciotomy, blood vessel or nerve exploration, removal of the necrotic tissue and hematoma, incision decompression, osseous fascia compartment). Similarly, the classification criteria may be used to predict prognosis. If the score is less than 9, the prognosis is likely to be good, and when the score is greater than 9, the prognosis is likely to be poor. However, in order to improve further studies, they should have a greater sample size of patients.

Muscle injuries are the most common injuries in patients with closed limb fracture. Recently, an increasing number of orthopedic surgeons have started to consider muscle injury as more important than limb fracture itself, because it is closely related to the functional recovery of the upper limb and lower limb. Although clinical evaluation remains the mainstay of the early and accurate diagnosis of a muscle injury, posttraumatic local oedema and severe pain can limit physical examination, and even complete muscle tears can be missed. Therefore, an early diagnosis can reduce patient discomfort and guide the decision of whether to implement surgical or conservative treatment [20].

There are two diagnostic imaging methods, ultrasonography and MRI, that can be used for an early diagnosis of muscle injury. Compared with ultrasonography, MRI seems to be superior for diagnosing and predicting the outcome of patients with muscle injuries. The MRI measurements of the lesion size, including height on longitudinal sections above the cross-sectional surface, may be useful. However, the available data are limited and contradictory, particularly regarding the influence of the initial lesion size on recovery time and recurrence risk after acute hamstring strains **[21]**.

Chan et al., **[18]** tried to integrate location of the injury, defined as the involvement of the proximal or distal musculotendinous junction or muscle body, with precise three-grade MRI- and US-based severity assessment systems. Moreover, a further sub-classification of injuries directly affecting the muscle body was suggested, specifying proximal, middle or distal location and fascial involvement. The value of this anatomical diagnosis lies in the fact that the distance of the hamstring lesion from the ischial tuberosity has been directly correlated with return to sport in sprinters.

US is not the method of choice for classifying extrinsic muscle injuries, but in mild injuries US may show the muscle as hyperechoic without tearing of the muscle fibers, in moderate injuries US may show frayed muscle fibers involving less than 50% in the axial plane, and in severe injuries US may show hematoma involving most of the muscles. Intrinsic injuries are categorized into three grades based on the extension of the lesion: Grade 1 involves a few muscle fibers within a bundle; in grade 2, the damaged fibers occupy up to 3/4 of the involved portion of the muscle; in grade 3, more than 3/4 is damaged and the lesion may involve the entire muscle belly (complete rupture). The role of US is to assess the longitudinal extent of the lesion, calculate the volume of the hematoma and detect possible compression of the adjacent structures **[22]**.

Conclusion:

In conclusion, ultrasonography is useful for diagnosing acute muscle injury associated with limb fracture. The ultrasound classification criteria for muscle injury can be used to predict the severity of injury and guide decision on the type of treatment. However, the criteria need to be verified on a larger sample of patients, and some sections of the proposed criteria may require a more detailed analysis.

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التقييم بالموجات فوق الصوتية لإصابة العضلات المصاحبة لكسر الأطراف المغلقة

وفقاً للآلية الممرضة، تُصنف إصابات العضلات على أنها إصابات خارجية مثل الكدمات الجروح المخترقة، حيث يتدفق موقع الآفة إلى موقع الصدمة، والإصابات الداخلية الناجمة عن الانقباض والاستطالة المعاصرة للعضلات مما يؤدى إلى تدمير العضلات عند التقاطع العضلى.

عضلات الهيكل العظمى هى أكبر كتلة أنسجة فى جسم الإنسان، وتمثل حوالى ٥٠٪ من وزن الشخص العادى. تمثل كسور الأطراف السفلية ما يقرب من ثلث جميع الكسور وقد تؤدى إلى وفيات ومراضة كبيرة.

يمكن أن يكون التصوير مفيداً لتأكيد الإصابة وتحديد الموقع الدقيق والعضلات المعنية. يمكنه تقييم مدى الإصابة وبالتالى توجيه العلاج. يمكن أن يساعد التصوير فى تحديد المضاعفات بعد إصابة العضلات التى تتطلب تدخلاً جراحياً أو تتطلب تأخيراً فى العودة إلى النشاط البدنى

يجب أن يسبق الفحص بالموجات فوق الصوتية للمريض المصاب بإصابة عضلية مشتبه بها دائماً تقرير دقيق عن التاريخ الطبى للمريض بما فى ذلك آلية الإصابة والأعراض والألم المحتمل وفقدان القوة والتقييم السريرى الدقيق الذى قد يكشف عن وجود كتل أو تغيرات مورفولوجية فى الجزء التشريحى قيد الدراسة.

تحسنت دقة صور الموجات فوق الصوتية بسرعة فى السنوات الأخيرة. توفر آلات الموجات فوق الصوتية ذات المحولات الخطية عالية التردد (MHz ١٥e١٢) دقة صورة أفضل وتستخدم على نطاق واسع لتقييم هياكل الأنسجة الرخوة السطحية مثل العضلات والأوتار والأربطة والجراب. لذلك يشار إليها عادة بأسم آلات الموجات فوق الصوتية للعضلات الهيكلية (MSUS).

يستخدم الأطباء بشكل متزايد الموجات فوق الصوتية (الولايات المتحدة) لتوجيه الإطار الزمنى للعودة إلى النشاط. تعتبر العودة المبكرة إلى النشاط عاملاً مهماً لأى مريض ولكنها عامل حاسم لرياضى النخبة الذى يريد تقلل الغياب عن التدريب والمنافسة.

تهدف الدراسة إلى تقييم إصابة العضلات المرتبطة بكسر الأطراف المغلقة العلوية والسفلية باستخدام الموجات فوق الصوتية، وتطوير معايير تصنيف الموجات فوق الصوتية لإصابة العضلات.

هذه الدراسة عبارة عن دراسة مرجعية، وقد أجريت على مريضاً يعانون من كسور مغلقة فى الأطراف وإصابة عضلية فى قسم الأشعة التشخيصية بمستشفيات عين شمس، خلال أشهر.