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Accuracy of Diagnosis of Distal Radial Fractures by Ultrasound

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ABSTRACT

Background: although distal radial fracture account up to 20% of all fractures, it forms the most common fracture in upper extremities**.** Distal radial fracture has six types the most common one is Colle's fracture. The gold standard for diagnosis of distal radial fracture is conventional radiograph. Despite using ultrasound in tendon rupture, localizing foreign bodies, ultrasound started to be used for diagnosing bone fracture especially distal radius. **Aim of the work:** this study aimed to detect the accuracy of ultrasound in the diagnosis of distal radial fracture. **Patients and methods:** this was a selective prospective case series study in the Emergency Department, Al-Jumhoori Teaching Hospital,78 patients were included in this study, their age ranged between 6-45 years with mean age 17.1. 59 were males and 19 females. Duration of the study was one year (January2013 - January 2014). **Results:** by analyzing data of 78 patients for distal radial fracture ultrasound and comparing the results with the gold standard conventional radiograph we found that sensitivity of ultrasound in detecting fracture was 95.5%, specificity 100%, accuracy 96.15%, positive predictive value 100% and negative predictive value 80%.
Conclusion: results of the current work demonstrated that ultrasound can be considered as a promising alternative to routine radiograph in diagnosis of the distal radial fractures and the horizon still open for further studies of use of ultrasound in diagnosis of other types of fractures.

Keywords: distal radial fractures, ultrasound, musculoskeletal ultrasound.

INTRODUCTION

Anatomy of radius bone

The radius is the lateral bone of the fore arm, and is homologous with the tibia of the lower limb. Radius along with ulna connect elbow to forearm. Radius has a head, a lower end and a shaft [1].

Distal end of Radius

The distal end tends to be turned slightly forwards, has somewhat triangular form. Its distal carpal articular surface is concave from backwards and slightly from side to side; it is divided into two facets by a slight antero-posterior ridge[2].

The anterior border is prominent and turned forwards , it is rough at its edge serves for the attachment of the anterior part of the capsule of the wrist-joint.**The posterior border** is rough, rounded and tubercular and it is grooved by many tendons [2].**The styloid process** lies to the lateral side of the distal end and broads at its base, it becomes narrow and pointed distally where by its medial cartilage-covered surface it forms the summit of the distal triangular articular area. On the medial side of the distal extremity the ulnar notch is placed for the reception of the head of the ulna[2]. It is concave before backwards and plane proximo-distally. It forms a rectangular edge, by its inferior margins, which separates it from the distal carpal surface [2].

Fractures

Definition

Fracture is a break in structural continuity of the bone. It may be no more than a crack, a crumpling or a splintering of the cortex, more often the break is complete and the bone fragments are displaced. If the overlying skin remains intact it is a closed (or simple) fracture; if the skin or one of the body cavities is breached it is an open (or compound) fracture, liable contamination and infection [3].

Clinical Features

Individuals with high activity levels appear to be at greater risk for fractures [4] . This group includes children and athletes participating in contact sports. It is also common in senile people Symptoms of fractures usually begin with pain that increases with attempted movement or use of the area and swelling at the involved site [5]. The skin in the area may be pale and an obvious deformity may be present. In more severe cases, there may be a loss of pulse below the fracture site, such as in the extremities, accompanied by numbness, tingling, or paralysis below the fracture [6].An open or compound fracture is often accompanied by bleeding or bruising [7]. Pain, bruising and swelling is a common symptom, but they do not distinguish a fracture from a soft tissue injury. Deformity was much more suggestive [3].

Diagnosis

Diagnosis begins immediately with an individual's own observation of symptoms [6]. Medical history and physical exam by a physician often reveals the presence of a fracture. X- ray of the injured area is the most common test used to determine the presence of a bone fracture. X- ray series performed at least two views of the area to

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confirm the presence of the fracture because not all fractures are apparent on a single x ray [5].

Some fractures are often difficult to see and may require several views at different angles to see clear fracture lines. In some cases, CT, MRI tests are required to demonstrate fracture [4]. Sometimes, especially with children, the initial X-ray may not show any fractures, but repeating seven to 14 days later may show changes in the bone(s) of the affected area [8].

Role of 2 X-ray diagnosis of orthopedic diseases and trauma: [3]

1-Two views: fracture or dislocation may not be seen in single X-ray film and at least two views must be taken.

2-Two Joints: in forearm and leg one bone may be fractured and angulated.

3-Two limbs In children: appearance of immature epiphysis may confuse the diagnosis of a fracture.

4-Two injuries: sever force often causes injuries at more than one level.

5-Two occasions: some fractures are notoriously difficult to detect soon after injury but another X-Ray examination a week or two later may show the lesion.

Distal Radius Fractures: a fracture of the distal radius occurs when the area of the radius near the wrist breaks. Distal radius fractures are very common. In fact, the radius is the most commonly broken bone in the forearm [9].

The distal end of the radius is subject to six distinct types of fractures, each with its own characteristic pattern of behavior. These are: [3]

1-**Colle's fracture**, it is transvers fracture of the radius just above the wrist with dorsal displacement of distal fragment. It is the most common of all fractures in the older people.

2-**Smith's fracture**, same as Colle's fracture with anteriorly displacement of distal fragment sometimes called reversed Colle's.

3-**Distal forearm fracture in children(Juvenile's Colle's),** these types occur among the commonest sites of childhood fractures ,it may occur through distal radial physis or in the metaphysis of one or both bones.

4-**Radial styloid fracture**, it is caused by forced radial deviation of the wrist and may occur after a fall, or when starting handle 'kicks back' so called Chauffeur's fracture.

5-**Barton's fracture**, it is a volar and dorsal fracture associated with volar or dorsal sublaxation of the carpus. It is sometimes mistaken for a smith's fracture.

6-**Fractures Involving the Physis (Salter Harris)** : [10-16,]

The weakest layer of the physis is the hypertrophic cell zone. The Salter and Harris classification system is based on the relationship of the fracture line to the physis and the prognosis for growth disturbance which can be classified into:

a-Type I physeal injuries occur when the epiphysis separates from the metaphysis. There are no associated fragments of bone, as the thick periosteal attachments surrounding the physis remain intact.

b-In a type II injury, the fracture line extends a variable distances along the physis and then out through a piece of metaphyseal bone. The periosteum overlying the metaphyseal fragment remains intact, whereas the periosteum on the opposite side of the fracture is torn away from the diaphysis, while remaining adherent to the epiphysis.

c-Type III physeal injuries are intra-articular. The fracture line extends intra-articularly from the epiphysis, with the cleavage plane continuing along the physis to the periphery.

d- In type IV injuries, the fracture line originates at the articular surface and extends through the epiphysis, the entire thickness of the physis, and continues through the metaphysis.

e-Type V injuries typically involve the knee or ankle and are the result of a profound compressive force transmitted to the physis, resulting in crushing of the chondrocytes in both the reserve and proliferative zones. Displacement of the epiphysis is usually only minimal despite the significant damage to the physis.

Cooney's universal classification of distal radial fractures (**Table 1-1**) was proposed in 1990. This system differentiates between extra-articular and intra-articular fractures, as well as between stable and unstable fractures; it was created as a treatment-based algorithm. Classification systems are based on the following two principles:

1-The classification should dictate the treatment.

2-The classification should suggest the long-term, functional results of treatment or be correlated with these anticipated results [17-22] .

Table 1-1: universal classification of distal radial fractures

Classification	Description
I	Nonarticular, nondisplaced
II	Nonarticular, displaced
A	Reducible, stable
B	Reducible, unstable
C	Irreducible
III	Articular, nondisplaced
IV	Articular, displaced
A	Reducible, stable
B	Reducible, unstable
C	Irreducible
D	Complex

Basic Ultrasound Imaging

When performing an ultrasound scan, fluid and structures comprising the approximate density of fluid is present at low acoustic impedance to the sound beam [(23,24).] Accordingly, this low acoustic impedance generates few echoes, which manifest themselves as dark displays on the screen. For example, ganglion cysts, fluid-filled sacs, abscesses, or other such structures generate few echoes and will appear as black areas on the ultrasound display.

At the other extreme, dense structures, such as bone, are highly reflective and deliver a high acoustic impedance in the realm of the sound beam, which makes that area of the screen bright white. [(27)] The remaining soft tissue (muscles, tendons, ligaments, etc.) will fall between grades of black and white contingent upon the quality of that system's digital scan conversion [(28)] .

Diagnostic ultrasound does not have the ability to penetrate bone; however, the surface of bone or peri-osteum can be examined for injuries, such as fractures or other inflammatory conditions of the peri-osteum including osteomyelitis. Only one surface of bone can be examined at one time. This lack of echoes through the surface of bone casts an acoustic shadow [(29)] .

PATIENTS AND METHODS

Design: This was a prospective, selective case series study.

Setting

The study was carried out at the Emergency Department Unit, Al-Jumhoori Teaching Hospital, Mosul, Iraq.

Period

This study was performed from1st January 2013 to 1st January 2014.

Sample Size

Seventy Eight suspected distal radial forearm fracture patients were enrolled in this study. There were 59 male (75.6%) and 19 female (24.4%), age range between 6-45 years old with mean age 17.1 years. Right forearm injury was 40 (51%), while left forearm was 38 (49%).

Inclusion criteria

Patients enrolled in this study were complaining from forearm trauma with suspected closed distal radius bone fracture admitted to Emergency Department within 24 hours of trauma, without previous history of fracture in same area and or history of metabolic bone diseases.

Exclusion criteria

1. Patient with distal radial fracture presented in more than 24 hours.
2. Patient had a Forearm trauma associated with serious other injuries that cannot tolerate our investigations.
3. Patient came with compartment syndrome.
4. Patient with open fractures.
5. History of previous deformity in same hand.
6. Patients out of the range of the study age.

MATERIAL

1. Medical ultrasound machine(Philips HD 11XE)(Figure 2-1).
2. Linear superficial probe (12L)MHZ.(Figure 2-2).
3. Contact gel(allogel).
4. Digital camera.
5. Surgical gloves.

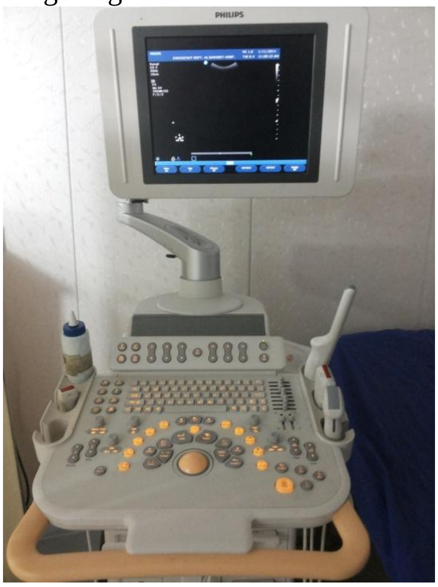

Figure 2-1: shows of ultrasound devise that use in the study (Philips HD 11XE). with high frequency transducer (12L) MHz

Figure 2-2: linear probe used in this study

History

In admission, proper history was collected from the patients or patient's parents concerning name, age, gender, residency, the date and the mode of the trauma, duration, mechanism of injury and symptoms of presentation.

Clinical examination

Patient's general examination included vital signs (Blood pressure, pulse rate ,respiratory rate) and level of consciousness then examined for the presence of ecchymosis, distal forearm swelling, hematoma, deformity, and/or limitation of movement with confirmation of distal pulse to exclude compartment syndrome.

Radiographic examination:

We used Shimadzu 500ma-125kv in our study as seen in **figure 2-3**. Clinical examination determined which radiographic views was best support a diagnosis. Standard views of the wrist included posteroanterior and lateral PA.

All 78 patients underwent radiograph of the wrist and lower radius to view the fracture.

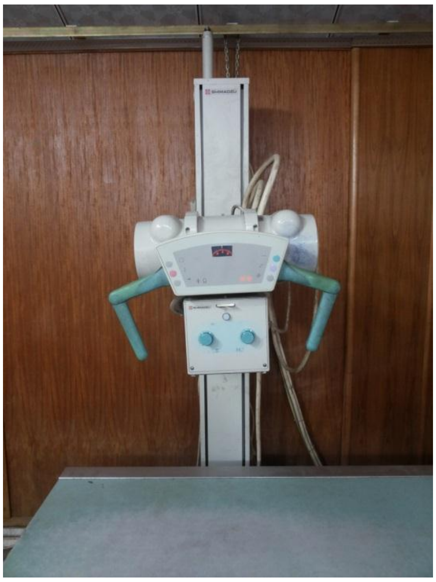

Figure 2-3: Shimadzu 500ma-125kv

Ultrasound examination

The patient or patient's parents fully informed about objective and procedures of our study.

For every patient there was a standard case sheet. It was filled by asking the patient or his relative.

Application of ultrasound, with superficial probes (12L MHZ), were used in the assessment of the traumatized sites of distal forearm . The examination was done as following:

Ultrasound examination carried out while the patient was placed in a supine position and an adequate amount of gel was applied on the skin over the fractured areas. The transducer was applied longitudinally to the fracture sites (Distal radius bone), parallel to its long axis. In this way, the ultrasound beam was oriented perpendicular to the bone surface producing sagittal views.

Ultrasound examination was carried out to the suspicious area (Distal radius bone) to identify the anatomy and continuity of these bones, then they focus on suspicious fracture site or sites. Two views accessible to sonography were selected which were typically affected by fractures of the distal radius bone. They were bone cortex of distal radius in horizontal and perpendicular views. The criterion for diagnosis was the discontinuity of bony cortex.

These views were evaluated also in conventional radiographic images. For the ultrasonographic examinations, a Philips, HD 11XE. ultrasound system with a linear transducer was employed.

Statistical Analysis

78 patients with suspicion of distal radial fracture were examined by conventional radiographs and ultrasound. The US examination was performed within 24 hours of admission to Emergency Medicine Department and when the patient condition was allowed for the examination. The case sheet was filled for each patient with related data.

Sensitivity (SE), specificity (SP), accuracy (AC), positive predictive value (PPV) and negative predictive value (NPV) were calculated with conventional radiograph as a gold standard.

The calculations were performed as follow:

Sensitivity (SE): is defined as the probability that the test states the condition is present, given it was actually present.

SE= total positive (TP)/(TP + false negative(FN) *100%)

Specificity(SP):is defined as the probability that the test states the condition was absent[(32).]

SP= total negative (TN)/(TN+ false positive (FP)*100%)

Accuracy (AC): is a degree of conformity of a measure to a standard or a true value[(33).]

AC= (TN+TP)/[(TP+TN)+(FP+FN)]*100%

Positive predictive value (PPV): is the ability of the test to correctly predict the presence of disease.

PPV=TP/(TP+FP)*100%

Negative predictive value (NPV): the ability of the test to correctly predict the absence of disease.

NPV= TN/(TN+FN)*100

True positive occurred when fracture was diagnosed by ultrasound and conventional radiograph. True Negative occurred when no fracture was diagnosed by ultrasound and conventional radiograph.False positive occurred when fracture was diagnosed by ultrasound with no conventional radiograph.

False negative occurred when fracture was not diagnosed by ultrasound, but it was diagnosed by conventional radiograph.

Ethical Evaluation or Approval

This study was approved by the Local Scientific Council of Arab Board of Health Specializations of Emergency Medicine in Iraq, and Mosul Ethical Research Committee, Directorate of Health in Ninawa.

RESULTS

3.1 Age and Gender distribution

The age distribution of the 78 patients included in this study ranged between 6-45 years with mean age 17.1 years. This study showed that 6-12 years with 35 patients the highest percentage of 44.9% followed by age group 19-45 years with percentage of 34.6% with 27 patients (**Table 3-1).**

Table 3-1: shows age distribution

Age in Years	No.	%
6- 12	**35**	**44.9**
13-18	**16**	**20.5**
19-45	**27**	**34.6**
Total	**78**	**100**

Gender distribution showed 59 male patients (75.6%) and 19 female patients (24.4%) with male/female ratio 3.1 as shown in **table 3-2.**

Table 3-2: incidence of fractures in association of sex in the studied sample

Gender	No.	Percentage
Male	59	75.6%
Female	19	24.6%

Residence and limb side injury the study sample

Urban residents show high percentage of distal radial fracture which is (60) patients (77%) versus rural residents which show (18) patients (23%) Table (3-3).

Table 3-3: incidence according to residence in the studied sample

Residency	No.	Percentage
Urban	60	77%
Rural	18	23%

This study showed the slightly increased percentage of right radius than left radius fracture (**Table 3-4**).

Table 3-4: incidence of fractures side of forearm in the studied sample

Limb	No.	Percentage
Right	40	51%
Left	38	49%

Mechanism of Injury

Regarding etiology of trauma falling on ground was the most common cause of distal radial fracture 45patients (57.7%). The direct trauma or assault to distal forearm form (22%) with 17 patients and the incidence of falling from height injuries 16 patients (20.5%). which was the least cause **(Table 3-5).**

Table3-5: showing mechanism that caused distal radial fracture

Mechanism of Trauma	No. of Patients	Percentage
Falling on ground	45	57.7%
Direct trauma	17	21.8%
Falling from height	16	20.5%

Imaging results

By analyzing results of ultrasound in patients suspected of distal radial fracture and comparing them with gold standard conventional radiograph **(Table 3-6),**we found that sensitivity of ultrasound was 95.5%, specificity was 100%, accuracy was 96.15%, positive predictive value was 100% and negative predictive value was 80%.

Figure 3-1 showed radiographic picture of suspected distal radius fracture, **figures 3-2 a, 3-2 b** showed ultrasonic picture of distal radial fracture.

Table 3-6: showed the results of ultrasound examination in comparison with radiograph of these patients.

	Positive X-Ray	**Negative X-Ray**
Positive Ultrasound	**True Positive = 63**	**False Positive = 0**
Negative Ultrasound	**False Negative = 3**	**True Negative = 12**

Figure 3-1: radiographic picture of distal metaphyseal fracture

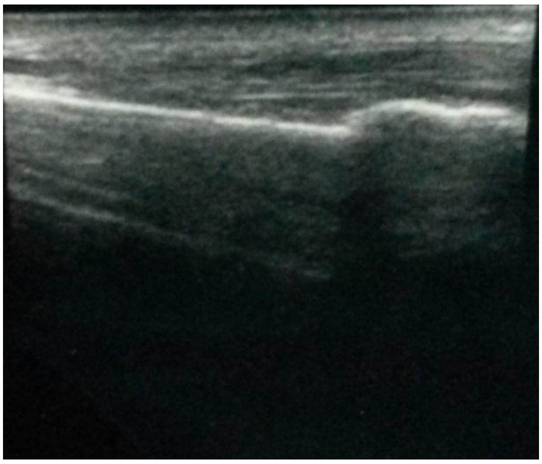

Figure 3-2 a : showing ultrasonic picture of distal radial fracture

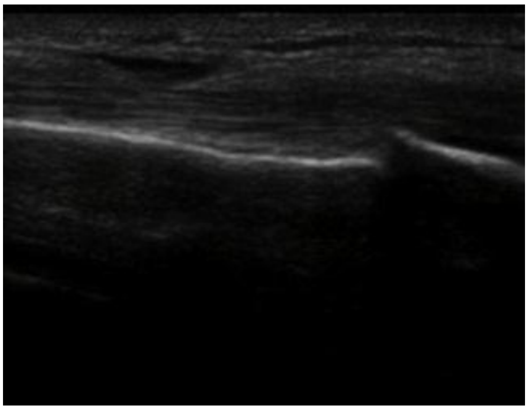

Figure 3-2b : showing ultrasonic picture of distal radial fracture

DISCUSSION

4.1 Demographic Analysis

Male patients were predominant in this study 75.6%, while female patients were 24.4%. This may be due to exclusion of old age patients whom prone to Colle's fracture and social factors that males are more involved in outdoor activities which make them more vulnerable to trauma and injury. found that incidence of distal radial fracture in male was 57.2% and female was 42.8% individuals were identified with a distal radius fracture. This may be due to wide range study sample.

Causes of fractures showed that falling on ground (57.7%) was the highest incidence followed by direct trauma (21.8%), this result is going with results of **Charles** [34].

Urban residence showed high incidence of falling from height when compared to those living in rural areas, this may be due to limited access of rural people to city hospitals in local situation.

This study showed that the age 6-12 years was common age for such injury (44.9%) because this range of age was very active or poor estimation of risks or no suitable areas to exercise the sport; second common age was 19-45 years (34.6%) this may be due to work injury, the age 13-18 years forms the least incidence age for this trauma (20.5%).

Ultrasound evaluation

Seventy eight patients were enrolled patients in this study to evaluate the accuracy of ultrasound in diagnosis of distal radial fracture in comparison with conventional radiograph.

By analyzing the results of this study 63 patients diagnosed by ultrasound and compared to positive radiograph, 12 patients showed negative result in both ultrasound and radiograph and 3 patients diagnosed by radiograph, but ultrasound showed negative result because these fractures were radial styloid fracture in two patients and one with chip fracture which were not seen in ultrasound. Sensitivity calculated and it was 95.5%, specificity was 100% and accuracy was 96.15%. A study from a United States of America Army battalion aid station enrolled 44 adults with various suspected fractures. Sonography was performed by an experienced emergency physician on-site using a portable Ultrasound machine. Radiographs were obtained for those subjects with positive US findings and for those with negative US findings. Sensitivity was 100% and specificity was 94% for the initial US screening [35] .

Pediatric radiologists in Germany concluded that US is a useful imaging modality for suspected fractures in pediatric trauma patients. In their 6-year study, 653 subjects underwent both US and radiograph evaluation of suspected fractures. For both modalities, sensitivity was 93% and specificity was greater than 99%. One of the strengths of this study was the wide range of fractures including hand, forearm, humerus, shoulder, lower extremity, ribs, sternum, and cranial bones[36].

In another German study, 3 trauma surgeons showed which types of fractures were most easily detected by US. They enrolled 163 children in a study of US as a screening test for injuries without obvious deformity. Overall accuracy was 87%. Accuracy was highest for simple fractures of the femur, humerus and forearm bones. It was lowest for compound fractures, small bone fractures and Salter-Harris type I injuries [37] .

In 2000, British Pediatric Radiologists were the first to demonstrate that US may be an alternative imaging modality for forearm fracture diagnosis. They enrolled 26 children ages 2 to 14 years with non-angulated forearm injuries. They found that the sensitivity and specificity in this small study were 100%, respectively [38] .

In addition, in 2000, a group of German trauma surgeons published their study of US for various non-deformed fractures. In contrast to the study by British radiologists, they noted lower specificity for US. Of 224 suspected fractures, more than half (139) were radius or ulna injuries. Within this subset, they found that sensitivity was 96% (95% CI, 89-99%), and specificity was 79%. Overall accuracy for forearm injuries was 124 of 139 examinations (89%).[37]

A 2009 multicenter study in Germany enrolled 93 children and ultimately found 77 fractures to forearm bones. Sensitivity was 94%, and specificity was 99% for US when compared to standard radiographs.[39]

Blinded review of US imaging is a key strength of a 2010 study in the United States because it showed how well fracture diagnosis can be made on the images alone. This study evaluated US imaging by pediatric emergency physicians specifically for distal forearm injuries without gross deformity in 101 children. When compared to radiographs, a blinded US interpretation had an overall accuracy of 94% . Sensitivity and specificity were 96%respectively[40] **.**

Weinberg *et al*. from the Mount Sinai School of Medicine began to define the amount of training needed for US-based trauma screening. They published the results of US evaluation of 348 suspected fractures in 212 children aged 1 to 25 years. Overall sensitivity for long bone fractures was 73%and specificity was 92%[41].

5.1-CONCLUSION

Ultrasound could be considered as a promising alternative to routine radiograph in the field of distal radial fractures.

Usage of 12L MHz probe is recommended for best resolution.

5.SUGGESTION

According to this work we can advise to start implantation of using ultrasound for initial diagnosis of distal radial fracture in Emergency Department and further studies on larger samples could be conducted for further evaluation.

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