

Inter-Observer Accuracy of “Fat Pad Sign” in Determining Radiological Elbow Joint Effusion with Different Levels of Experience

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Abstract

Background: Joint Effusion is considered as an important indicator of many joint morbid conditions. In the sitting of trauma, fat pad displacement in lateral elbow radiograph may be the only clue of occult fractures as it is referred to elbow effusion. Likewise, it's a sign of early internal joint morbidity in many articular diseases. The classic lateral radiograph is considered as the primary choice for determining elbow joint effusion because of being simple, available and reasonable tool.

Aim of Study: The current study aimed to evaluate the inter-observer accuracy of fat pad signs of elbow lateral radiograph in detecting elbow joint effusion with the impact of observer experience on it. MRI was used as the gold standard.

Patient and Methods: The current study is a descriptive validation study in which 52 patients were included prospectively in it. Inclusion criteria were positive elbow effusion by MRI with available lateral elbow radiograph within 3 days of the MRI study. Radiographs were read by 2 groups: Group I (2 senior radiology residents of 3 years' experience: Reader A & B), and group II (2 radiologists with MD degree, reader C & D). Each observer provided his readings by either proved effusion, denied effusion or asked for further evaluation. Readers were independently and blinded to the patients' clinical data.

Results: The diagnostic accuracy percentages of elbow effusion detection for each reader compared to MRI were calculated as follows: Proper detection were from 59.6% to 61% in low experience, and 76.9% to 82.7% in high experience. Missed cases were (19%) in low experience and (3.8%) to (7.7%) in high experience group. While cases needed further evaluation were 19.2% to 21.2% in low experience and in high experience were ranging from 13.5% to 15.4%. Then agreement between each reader were estimated. The same level of experience showed perfect agreement, (Kappa of 0.922 and 0.965). While lower agreement was detected in different experience group with Kappa of 0.51 to 0.641, which is moderate and substantial agreement.

Conclusion: The current study emphasizes that validity of radiographs in detection of elbow effusions widely varied

with levels of experience. MRI is important beside lateral radiograph for detection of elbow effusion especially in low experience to avoid missed occult fractures and early morbid joint affection.

Key Words: *Elbow – Effusion – Fat pad sign – Radiography – Levels of experience.*

Introduction

ELBOW joint is considered as a complex joint because it is composed of three closely connected articulations: The ulno-humeral joint, the radio-humeral joint, and the proximal radio-ulnar joint [1]. These articulations allow a combination of flexion, extension, pronation, and supination of the forearm [2].

The ulna articulates with the humerus at the trochlea, which is the grooved and rounded medial articular portion of the distal humerus. The articular portion of the ulna is formed by the olecranon process proximally and by the coronoid process more distally [3].

Elbow effusion can be concomitant with trauma, rheumatoid arthritis and inflammation. Septic arthritis results from an infection in a joint space from bacteria, fungus, virus, or even parasite, is considered as a cause of effusion as well [4,5].

Many previous studies had demonstrated that elbow effusions without radiographic evidence of a clear fracture represent underlying occult elbow fractures. And so, most of pediatric patients with elbow joint effusions without clear fractures gave a concern for underlying occult fracture [6,7]. Despite the fact that, pediatric elbow fractures is the most common childhood fractures, its accurate detection remains challenging and sometimes it is difficult to identify [6,7]. This might be due to many factors such as the preponderance of radiopaque

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cartilage, the variable appearance of ossification centers during skeletal growth, subtle and occult fracture patterns [6-8]. In the same manner in cases of septic arthritis, early detection of elbow effusion is crucial to decrease joint morbidity [9].

Radiographs have been the mainstay of initial imaging of the elbow, particularly in the pediatric trauma setting. It is very imperative to improve detection of elbow effusion in order to not miss the main evidence of occult elbow fractures and other early articular disease.

Elbow effusion can be detected on lateral radiograph by the secondary elevation of pre-articular fat by synovial fluid in the olecranon, coronoid, and radial fossae [10,12]. Elevation of fat can be seen at the olecranon fossa which was first reported in 1954 as posterior pad sign as a sign of elbow effusion and occult elbow fracture [10]. While fat elevation in the superimposed coronoid and radial fossae referred to the anterior fat pad sign, which was described shortly thereafter. Hence the fat pad sign described the elevated anterior lucency and/or a visible posterior lucency on a true lateral radiograph of a 90° flexed elbow [10,12].

The reported frequency of occult or initially missed acute fracture in pediatric patients, or undisplaced fractures with traumatic elbow effusion has ranged from 17% to 77%, disputed this association, the relationship between the presence of a positive fat pad sign and an occult fracture in children has come into question in variable studies [10,11].

The study aimed to evaluate the accuracy of routine radiography for the assessment of elbow effusion, using MR as the gold standard. Since many imaging findings became more accurate with experience of the readers, the study also aimed to investigate the effect of observer experience on the accuracy of detection of elbow effusion by using fat pad sign.

Patients and Methods

The current study is a descriptive validation study in which 52 patients (28 males and 24 females) were included prospectively. The age of patients ranged between 3 to 55 years (mean 20 year). Patients were referred from trauma unit, out-patients clinics and other hospital departments to Radiology department, Assiut University Hospital. All patients referred with symptoms suggest elbow joint trauma or articular morbidity. All patients underwent both lateral elbow radiograph and MRI study of the same joint. The study was carried out

between January 2018 and October 2019. The inclusion criteria of patients enrolled in the study were: Prove of elbow effusion by MRI and available lateral elbow radiograph of the same joint within 3 days of the MRI study. We exclude negative cases of elbow effusion and unavailable radiograph within two days from the MRI study. Ethical committee approval and patients consent was considered.

Effusion was diagnosed in the presence of fluid more than 3mm between bone and the capsule at the level of the trochlea or the capitulum as well as in the olecranon fossa. Each observer read 52 elbow radiographs of positive elbow effusion independently and blinded to the patients' clinical data. The observers team constituted of two groups with different level of experience. Group I: Consisted of two senior radiology residents (three years' experience) and group II: Of two senior radiologists with MD degree.

Each observer provided his reading either by proved effusion, denied effusion existence or asked for further evaluation (MRI). MRI was performed at 1.5T (Achieva, Philips) multiple planes and sequences were obtained, sagittal T1 and STIR, axial STIR and T2 fat sat, and coronal T1 and T2 fat sat. [(TR/TE 3900/60), matrix 256, slice thickness 5, interstice gap 1mm and field of view 12cm. The results of the radiograph from the radiologists were compared with the MR study, for each patient as a gold standard for the presence of effusion.

Statistical methods: Data entry and analysis were conducted using SPSS-21 (IBM Corp. Released 2012. IBM SPSS Statistics for Windows. Armonk, NY, USA). Percent agreement focuses on the number of codes which have been considered for their right (or related) data chunks by independent coders. Although it does not account for agreement that could occur by chance (the two coders may agree on some of the codes by chance), it is simple to transparently communicate how the method is used in a study. Chi-square test was used to compare between qualitative variables. Agreement between raters in diagnosis of effusion was examined using weighted Cohen's kappa coefficient (κ), Rater's response was assessed by a 3-point scale (0, No (no effusion); 1, Yes (Effusion); 2, Not Sure (for further assessment). Cohen suggested the Kappa result be interpreted as follows: Values ≤ 0 as indicating no agreement and 0.01–0.20 as none to slight, 0.21–0.40 as fair, 0.41–0.60 as moderate, 0.61–0.80 as substantial, and 0.81–1.00 as almost perfect agreement³. *p*-value considered statistically significant when $p < 0.05$.

Results

All readers provided their results blindly from each other results' and the MRI results (Table 1 & Fig. 1).

Table (1): Baseline description of study cohort diagnosis.

Parameter	n=52
<i>Low experience:</i>	
<i>Group I:A</i>	
• No effusion	10 (19.2%)
• Effusion	32 (61.6%)
• Need further investigation	10 (19.2%)
<i>Group II:B</i>	
• No effusion	10 (19.2%)
• Effusion	31 (59.6%)
• Need further investigation	11 (21.2%)
<i>High experience:</i>	
<i>C:</i>	
• No effusion	2 (3.8%)
• Effusion	43 (82.7%)
• Need further investigation	7 (13.5%)
<i>D:</i>	
• No effusion	4 (7.7%)
• Effusion	40 (76.9%)
• Need further investigation	8 (15.4%)

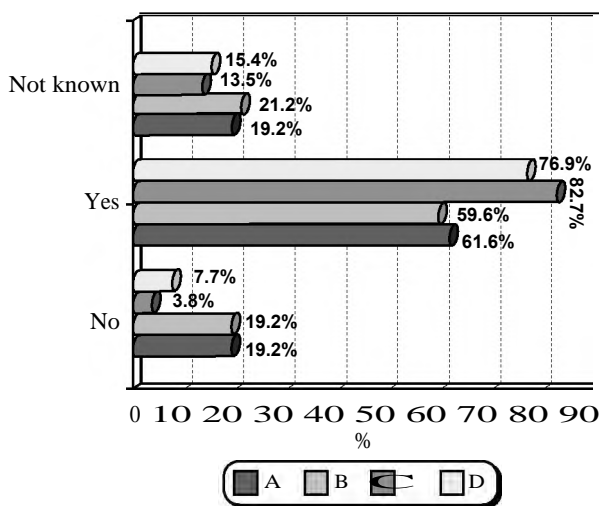


Fig. (1): Frequency of diagnostic entities among raters.

As illustrated in Table (1), Reader A: Provided proper diagnosis in 32 of 52 (61.6% of cases), wrong results in 10 of 52 (19.2%) and requested further modality in 10 of 52 (19.2%). While reader B: Was right in 31 of 52 (59.6%), wrong results in 10 of 52 (19.2%) and requested further modality in 11 of 52 (21.2%). As for the high experience, reader C: Provided proper diagnosis in 43 of 52 (82.7%), wrong results in only 2 of 52 (3.8%) and requested further modality in 7 of 52 (13.5%), lastly reader D: Was right in 40 of 52 (76.9%), wrong results in 4 of 52 (7.7%) and requested further modality in 8 of 52

(15.4%). So the different percentages of each group results are shown in Table (2).

Some cases were detected properly by the four readers as in (Fig. 2), while others were detected only by the two high experience readers, while low experience requested further evaluation as in (Fig. 3). While others were missed from all readers (Fig. 4).

Table (2): Baseline description of each group diagnosis.

	Low experience A&B	High experience C&D
Range of proper detection	61.6%-59.3%	82.7%-76.9%
Range of missed cases	19.2%	3.8%-7.7%
Range of further modality request	19.2%-21 %	13%-15.4%

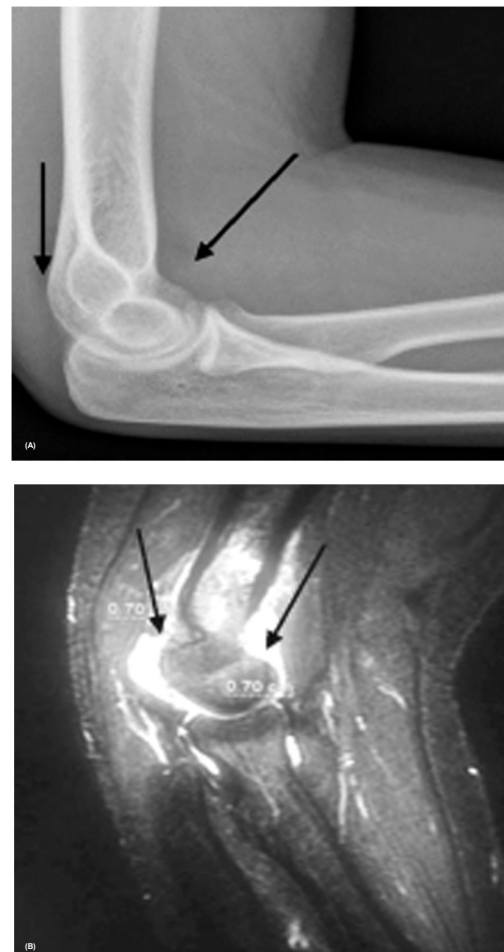


Fig. (2): [30 years old male patient, with history of trauma and elbow pain with no bone gross fractures]. Readers were blinded to the clinical data. (Fig. 2a): Lateral radiograph of the elbow joint demonstrates a positive fat pad sign with no radiographic evidence of a fracture. The anterior lucency (long arrow) represents the elevated anterior fat pad, and the posterior lucency (short arrow) represents the elevated posterior fat. Fig. (2b) MRI sagittal STAIR showed significant effusion in the anterior and posterior recesses measuring 7.0mm in each recess (arrows).

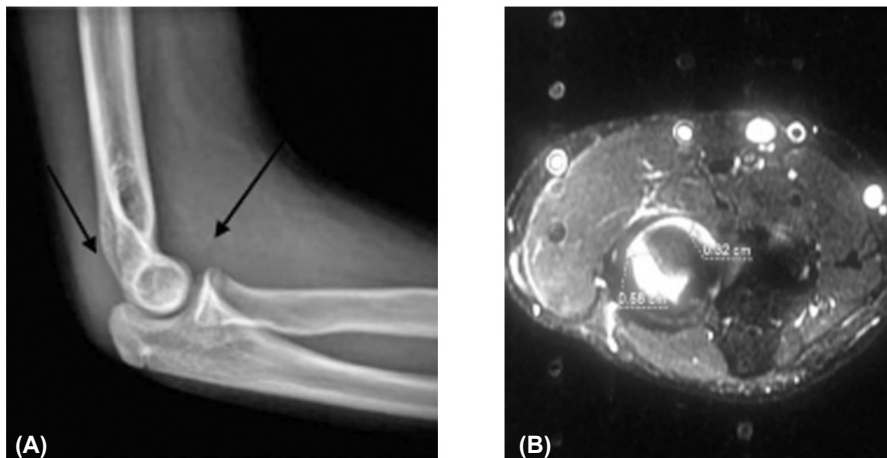


Fig. (3): [11 years old male patient, with history of trauma and elbow pain with no bone gross fractures] readers were blinded to the clinical picture. Fig.(3a): Lateral radiograph of the elbow joint demonstrates a positive fat pad sign with no radiographic evidence of a fracture. The anterior lucency (long arrow) represents the elevated anterior fat pad, and the posterior lucency (short arrow) represents the elevated posterior fat pad. Fig. (3b): MRI revealed effusion seen at the level of the olecranon in axial STIR- weighted images (Fig. 3b) measuring 3.2mm in the anterior recess (white arrows) and 5.8mm in the posterior recess (arrows).

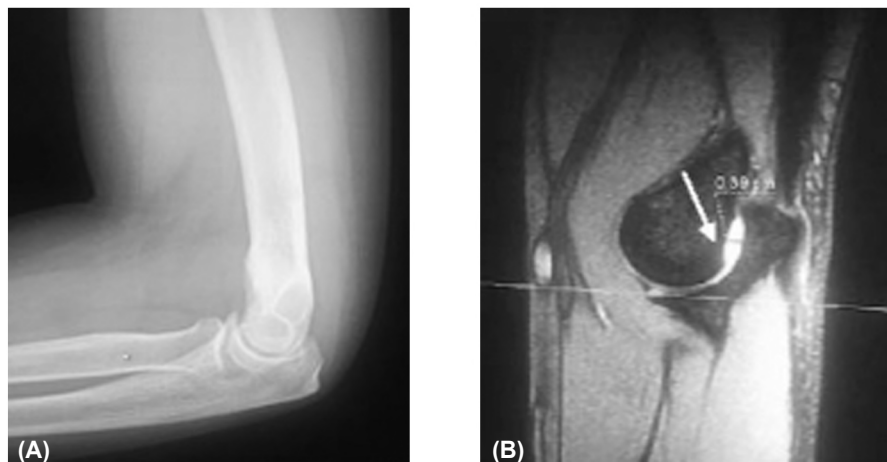


Fig. (4): [40 years old female patient, diagnosed as rheumatoid arthritis and complained of multiple joint pain included the elbow] readers were blinded to the clinical data. (Fig. 4a): Lateral radiograph of elbow in which fat pad signs either anterior or posterior were hardly detected. (Fig. 4b) minimal effusion seen in sagittal STIR-weighted images at the level of the trochlea measuring 3.9mm in the anterior recess (arrows).

Regards the agreement between raters in diagnosis of effusion was examined using weighted Cohen's kappa coefficient (κ_w). Rater's response was assessed by a 3-point scale (Tables 3-5).

The agreement between the two low experience readers A & B resulted in Weighted Kappa Coefficient of 0.965 (perfect agreement) in Table (3). In the same manner, the agreement between the high experience reader's C & D were 0.922 (perfect agreement). Which means that readers from the

same level of experience have perfect agreement in their results (Table 4).

While lower agreement was detected between readers from different experience level. For instance, agreement between A and the two high experience C & D showed Weighted Kappa Coefficient of 0.538 (moderate agreement) and 0.641 (substantial agreement) respectively. The same results were detected when compared each of low experience with each of high experience as shown in (Table 5). The agreement between each reader and others were summarized in Table (6).

Table (3): Raters agreement with others regarding diagnostic entities.

	Rater A			Total
	No	Yes	NS	
<i>Rater B:</i>				
No	10 (19.2%)	0 (0%)	0 (0%)	10 (19.2%)
Yes	0 (0%)	31 (59.6%)	0 (0%)	31 (59.6%)
NS	0 (0%)	1 (1.9%)	10 (19.2%)	11 (21.2%)
Total	10 (19.2%)	32 (61.5%)	10 (19.2%)	52 (100%)
Weighted kappa coefficient (95% CI)	0.965 (0.798-0.998)			$p < 0.001$
Chi-square test	97.759			$p < 0.001$
<i>Rater C:</i>				
No	2 (3.8%)	0 (0%)	0 (0%)	2 (3.8%)
Yes	8 (15.4%)	32 (61.5%)	3 (5.8%)	43 (82.7%)
NS	0 (0%)	0 (0%)	7 (13.5%)	7 (13.5%)
Total	10 (19.2%)	32 (61.5%)	10 (19.2%)	52 (100%)
Weighted kappa coefficient (95% CI)	0.538 (0.501-0.659)			$p < 0.001$
Chi-square test	42.326			$p < 0.001$
<i>Rater D:</i>				
No	4 (7.7%)	0 (0%)	0 (0%)	4 (7.7%)
Yes	5 (9.6%)	32 (61.5%)	3 (5.8%)	40 (76.9%)
NS	1 (1.9%)	0 (0%)	7 (13.5%)	8 (15.4%)
Total	10 (19.2%)	32 (61.5%)	10 (19.2%)	52 (100%)
Weighted kappa coefficient (95% CI)	0.641 (0.513-0.751)			$p < 0.001$
Chi-square test	47.320			$p < 0.001$

Table (4): High experience raters agreement with others regarding diagnostic entities.

	Rater C			Total
	No	Yes	NS	
<i>Rater D:</i>				
No	2 (3.8%)	2 (3.8%)	0 (0%)	4 (7.7%)
Yes	0 (0%)	38 (73.1%)	2 (3.8%)	40 (76.9%)
NS	0 (0%)	3 (5.8%)	5 (9.6%)	8 (15.4%)
Total	2 (3.8%)	43 (82.7%)	7 (13.5%)	52 (100%)
Weighted kappa coefficient (95% CI)	0.922 (0.804-1.000)			$p < 0.001$
Chi-square test	44.183			$p < 0.001$

Discussion

Elbow joint consists of three highly congruent articulations; the radio-capitellar, ulno-humeral and proximal-radioulnar joints. It contains small amount of synovial fluid, formed by the lining connective tissue cells with average volume of 10-20mm normally presents in asymptomatic joints [13-15]. When the amount of fluid exceeds the normal physiological amount for the joint it leads to effusion. Joints effusions are an important indicator

Table (5): Raters B agreement with others regarding diagnostic entities.

	Rater B			Total
	No	Yes	NS	
<i>Rater C:</i>				
No	2 (3.8%)	8 (15.4%)	0 (0%)	10 (19.2%)
Yes	0 (0%)	31 (56.9%)	0 (0%)	31 (59.6%)
NS	0 (0%)	4 (7.7%)	7 (13.5%)	11 (21.2%)
Total	10 (19.2%)	43 (82.7%)	7 (13.5%)	52 (100%)
Weighted kappa coefficient (95% CI)	0.510 (0.501-0.649)			$p < 0.001$
Chi-square test	38.478			$p < 0.001$
<i>Rater D:</i>				
No	4 (7.7%)	5 (9.7%)	1 (1.9%)	10 (19.2%)
Yes	0 (0%)	31 (56.9%)	0 (0%)	31 (59.6%)
NS	0 (0%)	4 (7.7%)	7 (13.5%)	11 (21.2%)
Total	10 (19.2%)	43 (82.7%)	7 (13.5%)	52 (100%)
Weighted kappa coefficient (95% CI)	0.611 (0.508-0.703)			$p < 0.001$
Chi-square test	43.854			$p < 0.001$

Table (6): Agreement between same and different level of experience.

Agreement between	Weighted kappa coefficient	
Same level of experience A&B (low)	0.965	Perfect agreement
Same level of experience C & D (high)	0.922	Perfect agreement
Different level of experience A& C	0.538	Moderate agreement
Different level of experience A&D	0.641	Substantial agreement
Different level of experience B&C	0.510	Moderate agreement
Different level of experience B&D	0.611	Substantial agreement

for many articular and non-articular disorders. Aside from trauma, joint fluid may be increased secondary to infections, injuries, articular disease, rheumatoid or internal derangements [5].

The ‘fat pad sign’ is referred to radiological visualization of the extracapsular extra synovial fatty tissue which is situated at the anterior and posterior aspects of the elbow joint and can be seen on the true lateral radiograph of the flexed elbow, as a sign of an intra-articular effusion. In

the setting of trauma, it happened due to haemarthrosis (blood in the joint) secondary to a bone fracture. This is often the only radiographic sign of a bone injury [11,12].

Radiographs are the mainstay of elbow imaging in trauma as it may be the only sign for underlying occult injury. Post-traumatic effusion without a visible bone fracture usually indicates a radial head fracture in an adult, and a supracondylar fracture of the distal humerus in a child [5,11,12].

The association between joint fluid and the presence of a radiological occult fracture has been widely discussed in previous studies, and revealed the established hypothesis is that an elbow effusion following trauma referred to an indirect sign of significant bony injury. This hypothesis is supported by several studies based on the presence or absence of periosteal reaction on follow-up radiographs [10].

Many studies reported that more than 90% of displacement of the fat pad prove to have an occult fractures on either initial (at time of injury) or subsequent radiographs (at follow-up) [7,10].

Donnelly et al., [16] reported that only 54% of cases with an isolated joint effusion with no detected fracture on initial presentation, had evidence of a healing fracture on follow-up later on. This because occult fracture can be easily missed at initial radiograph, but can be detected easily as healed fracture. Additionally, they reported that 78% of cases with occult fractures still show persistent effusions on the follow-up imaging [7,10].

Hence it is crucial to consider carefully the occult fracture in cases of positive radiological fat pad sign or even suspicion of it which denoting joint effusion.

Despite this, there is still no absolute agreement on the exact percentage of occult fractures when finding a positive fat pad sign. According to the literature, it varies considerably between 17 and 89% [11].

On other hand, other authors had disputed this association and claimed that an isolated joint effusion in the absence of visualized fracture is not necessary to be concomitant with a radiographically occult fracture [7].

Aside from elbow trauma, the fat pad sign frequently occurs in non-traumatic elbow disease which caused displacement and distention of the joint capsule. It has been founded in various diseases, such as hemophilia, rheumatoid arthritis, gout, osteoarthritis, and acute pyarthrosis [12,18].

It also detected in septic arthroplasty, synovitis and potentially olecranon bursitis [12,19].

It can be expected to occur whenever there is distention of the joint capsule [18].

Utilization of MRI in suspected cases of elbow effusion allowed more conclusive results for effusion detection even for minimal amount. MRI is also providing more assessment of bone marrow edema, disruption of tendons, muscles, nerves, vessels, subcutaneous soft tissue and any other soft-tissue injuries [5].

As experience had a significant impact on imaging reading, we investigated its role to improve radiograph detection of elbow effusion. In the current study the same experienced readers showed perfect agreement in their results (w Kappa of 0.922 to 0.965), while between different levels of experience groups were moderate to substantial agreement. This emphasizes that level of experience has an important impact on detecting the effusion by radiography. Similarly, the percentage of proper diagnosis was significantly affected by experience as it ranged from [61.6% - 59.3%] in low experience to [82.7%-76.9%] in high level. Missed cases also showed significant variation among the two groups, low experience reported [19.2%] while the high experience reported lower percentage of [3.8% - 7.7%]. In the same manner, cases dedicated for MRI were [19.2% to 21.2%] in low experience while were [13.5%-15.4%] in high.

Hence the current study reported an overall detection of elbow effusion by radiograph varied from 60%-80%, which is somehow satisfactory as preliminary tool and it also necessities the role of MRI in indeterminate cases [5].

In the current study, about 15% of the missed cases attributed to lack of experience, and about 15.4% to 11.5% of MRI requests were obtained due to same cause. The variation of detection of effusion may attributed to the small amount of fluid which may be missed with low experienced radiologists. However, the accuracy of radiograph in detection of elbow effusion was assessed in many previous studies, and revealed the of superiority of MRI, but depending on MRI is also expensive, and scheduling a patient for examination is difficult [20,21]. Accordingly, we are still in need to improve the accuracy of radiograph to reduce chances of missing cases. Experience played a significant role in improving the radiograph performance and decreasing the missed cases beside the optimal technical factors and positioning for optimal detection of the fat pad sign.

The limitations of the study were absent of relation between the size of an elbow effusion and reader's results. Another limitation of this study was the different patients age groups.

Conclusions:

Conventional lateral radiograph is still the primary modality for the elbow effusion detection. The presence of a positive fat pad sign should alert for the possibility of occult fracture or intra-articular diseases. Readers with high experience convinced a better result in radiographic accuracy of elbow effusion. MRI is still essential in suspicion when fat pad sign is not conclusive especially in low experience groups.

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دقة المراقبة من "علامة وسادة الدهون" في تحديد انصباب مفصل الكوع الإشعاعي مع مستويات مختلفة من الخبرة

الخلفية: يعتبر الانصباب المشترك مؤشراً هاماً لكثير من الأمراض المفصالية. في حالة الصدمات النفسية، قد يكون إزاحة وسادة الدهون التي يشار إليها إلى وجود انصباب المرفق هو الدليل الوحيد للكسور الخفية. وبالمثل، إنها علامة على حدوث اعتلال مفاصل داخلي مبكر في العديد من الأمراض المفصالية. يعتبر التصوير الشعاعي الجانبي الخيار الرئيسي لتحديد انصباب مفصل الكوع بسبب كونه أداة بسيطة ومتاحة ومعقولة.

هدف البحث: قيمت الدراسة الحالية الدقة التشخيصية للأشعة في كشف انصباب المرفق مع تأثير تجربة المراقب عليها. تم استخدام التصوير بالرنين المغناطيسي كمييار ذهبي.

المريض والطرق: أدرجت ٥٢ مريضاً بأثر رجعي في الدراسة. كانت معايير الاشتمال انصباب الكوع الإيجابي بواسطة التصوير بالرنين المغناطيسي مع الأشعة السينية الكوع المتاحة في غضون ٤٨ ساعة من دراسة التصوير بالرنين المغناطيسي. تمت قراءة صور الأشعة بواسطة مجموعتين: المجموعة الأولى (٢ من كبار سكان الأشعة: القارئ أ و ب)، والمجموعة الثانية (٢ من كبار أخصائيي الأشعة الحاصلين على درجة الدكتوراه، والقارئ C & D) قدم كل مراقب قراءته بشكل مستقل وأعمى عن البيانات السريرية للمرضى إما عن طريق الانصباب المثبت، أو رفض الانصباب أو طلب مزيد من التقييم.

النتائج: تم تقدير النسبة المئوية لكل قارئ والاتفاق بينهما. في مجموعة الخبرة المنخفضة: كان التشخيص المناسب من ٥٩.٦٪ إلى ٦١٪، في حين كان في تجربة عالية ٧٦.٩٪ إلى ٨٢.٧٪. كانت الحالات المفقودة في التجربة المنخفضة (١٩٪) والمجموعة ذات الخبرة العالية (٣.٨٪) إلى (٧.٧٪)، في حين أن الحالات التي تحتاج إلى مزيد من التقييم كانت ١٩.٢٪ إلى ٢١.٢٪ في تجربة منخفضة بينما تراوحت في التجربة العالية بين ١٢.٥٪ إلى ١٥.٤٪. أظهر الاتفاق بين نفس المستوى من الخبرة اتفاقاً تاماً، (كبا ٠.٩٢٢ و ٠.٩٦٥). في حين تم اكتشاف اتفاق أقل في مجموعة تجربة مختلفة مع kappa من ٠.٥١ إلى ٠.٦٤١، وهو اتفاق معتدل وكبير.

استنتاج: تباينت صلاحية الأشعة في اكتشاف انصباب الكوع على نطاق واسع مع مستويات الخبرة. تؤكد الدراسة الحالية أن الاعتماد على الصور الشعاعية كطريقة للكشف عن الكوع يحتاج إلى مزيد من التحسن لتفادي حدوث كسور غامضة لمرض المفاصل الكوع.