



# Diagnostic accuracy of the shaft-condylar angle for an incomplete supracondylar fracture of elbow in children

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Received: 8 April 2019 / Accepted: 29 June 2019 / Published online: 4 July 2019  
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## Abstract

**Objective** The incomplete supracondylar fracture of distal humerus poses difficulty for diagnosis. A shaft-condylar angle and a lateral capitellohumeral angle, which can be measured from a routine lateral view of plain film of the injured elbow, may be a clue to assist in the diagnosis. Nevertheless, no literature explains about the accuracy of these angles for diagnosis. Our goal is to investigate the accuracy, sensitivity, specificity, positive predictive value and negative predictive value of the shaft-condylar angle and the lateral capitellohumeral angle for diagnosis of the incomplete supracondylar fracture.

**Methods** The retrospective study in tertiary care hospital was performed from January, 2014, to January, 2018. The patients aged below 15 years with elbow injury were recruited. The patients with complete fracture were excluded. The rest of the patients were divided into four groups which consisted of incomplete fracture and non-fracture group. With the shaft-condylar angle at 40° and the lateral capitellohumeral angle at 50°, the diagnostic accuracy of both angles were calculated.

**Results** A total number of patients were 53. For the SCA, the accuracy was 92%, the sensitivity was 76%, the specificity was 93%, the positive predictive value was 92% and the negative predictive value was 93%. For the LCHA, the accuracy was 70%, the sensitivity was 55%, the specificity was 72%, the positive predictive value was 67% and a negative predictive value was 72%.

**Conclusion** The shaft-condylar angle less than 40° in lateral elbow film might be a useful tool for diagnosis of the incomplete supracondylar fracture in pediatric patients with elbow injury.

**Keywords** Shaft-condylar angle · Humero-trochlear angle · Gartland type II · Supracondylar fracture

## Introduction

Elbow is the second most common site of injury in the upper limbs in children. Among these fractures, supracondylar fracture accounts for 55–75% of the distal humerus [1]. This fracture is one of the most common injuries requiring surgery and associated with a high prevalence of various complications, such as nerve injuries or cubitus varus [2].

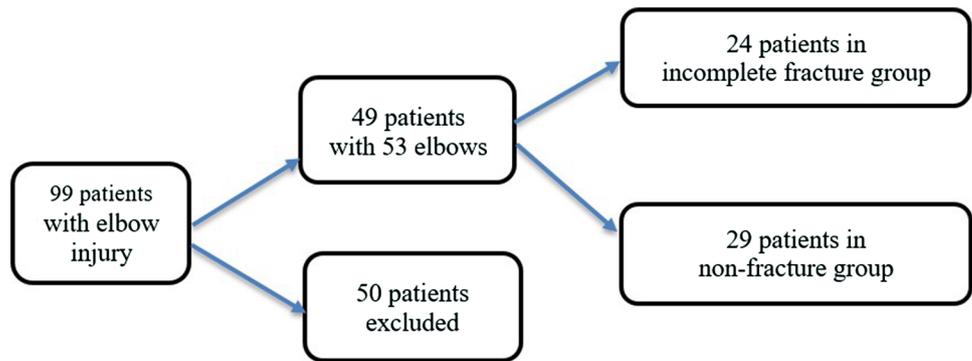
The typical mechanism of injury is a fall onto an out-stretched hand which leads to a hyperextension load on the arm [3]. The supracondylar area of the humerus is a weak point of the bone which tends to be broken. Therefore, children with elbow injury, who has limit elbow range of motion, should be sent for imaging. Gartland's classification, based on the lateral radiograph, is broadly used for supracondylar fractures as it can help guide treatment. In Gartland type I, there is no or minimal displacement of fracture that is less than 2 mm. In type II, the fracture displaces more than 2 mm with intact-hinged posterior cortex. In Gartland type III, there is no cortical contact on supracondylar area [4].

The gold standard for diagnosis of supracondylar fracture of humerus depends on plain film. Posterior fat pad sign and an abnormal anterior humeral line (AHL) are diagnostic clues in type I and II, respectively. However, in an incomplete fracture without significant displacement or in children younger than 4 years old that anterior humeral line may not

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**Fig. 1** Flowchart of patient recruitment



dissect the middle third of the condyle, the diagnosis may be difficult.

Other parameters that can be evaluated in the lateral elbow film are a shaft-condylar (humero-trochlear) angle (SCA) and a lateral capitellohumeral angle (LCHA) (Fig. 1). However, diagnostic accuracy of these parameters for supracondylar fracture is still limited.

The SCA was reported as an option to evaluate the treatment outcome of supracondylar fractures in children [5]. A value more than  $40^\circ$  in lateral elbow film is considered normal [6]. For LCHA, a value less than  $50^\circ$  is considered normal. We hypothesize that this angle could be an option to evaluate the incomplete fracture of the supracondylar area in children. Therefore, the primary objective of our study is to evaluate the accuracy, sensitivity, specificity, positive predictive value and negative predictive value of the SCA and the LCHA for diagnosis of the incomplete supracondylar fracture of the elbow.

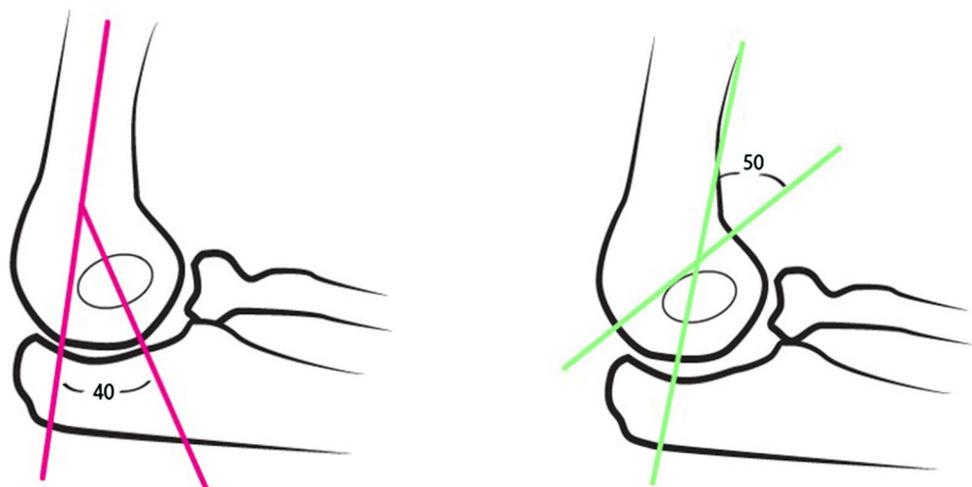
## Methods

A retrospective review was conducted after approval was obtained from the local institutional review board. Children aged below 15 years with elbow injury presented to the MSMC hospital from January, 2014, to January, 2018, were recruited.

The patients with complete supracondylar fractures and other fractures around the elbows were excluded. Then, the rest of the patients were classified into two groups which included the incomplete fracture and the non-fracture groups.

The incomplete fracture group consisted of the patients with crack or breakage of anterior cortex of the supracondylar area of distal humerus, the positive posterior fat pad sign, the anterior humeral line dissected anterior or anterior one-third to the capitellum, which were not shown in the contralateral elbow, the radiographic evidence of bone healing such as callus formation or subperiosteal bone formation in the follow-up X-rays. The non-fracture group inclusion criteria were the patients without any sign of fracture of the

**Fig. 2** From lateral radiographs of elbow, the angle between the axis of distal humerus shaft and axis of the distal humeral condyle is called the shaft-condylar angle (SCA). The lateral capitellohumeral angle (LCHA) was the angle between anterior cortex of humerus and line drawn along proximal border of the capitellum ossification center





**Fig. 3** Example of case in the fracture group

bone with no sign of bone healing in the follow-up X-ray and patients with the diagnosis of pulled elbow.

In both groups, the measurement of the SCA and the LCHA was taken by two orthopedic surgeons. One of them is a general orthopedist and the other is a pediatric orthopedist. After that, the patients were divided into four groups which consist of an incomplete fracture group

**Table 1** 2 by 2 table for diagnostic test accuracy calculation

SCA	Fracture	Non-fracture
< 40	a	b
> 40	c	d
Total		
LCHA	Fracture	Non-fracture
> 50	a	b
< 50	c	d
Total		

**Fig. 4** Example of case in the non-fracture group



(Fig. 2) with the angle less than 40° (a) and more than 40° (c) and the non-fractures group (Fig. 3) with the angle less than 40° (b) and more than 40° (d). (Table 1) For the LCHA, we used the cut point at 50°. The diagnostic accuracy of the test were calculated as a sensitivity, a specificity, a positive predictive value and a negative predictive value.

**Statistical analysis**

Characteristics of patients were described using median and percentages. The accuracy, sensitivity, specificity, positive predictive value and negative predictive were calculated from the 2 by 2 table. Calculation solution: Accuracy =  $a + d/a + b + c + d$ , Sensitivity =  $a/c + d$ , Specificity =  $d/b + d$ , PPV =  $a/a + b$ , NPV =  $d/c + d$ .

**Results**

A total of 99 patients present with elbow injury: 50 were excluded and 49 patients with 53 elbow films, which are divided into 24 elbows in fracture group and 29 elbows in non-fracture group (Fig. 4). In the fracture group, there were 22 elbows with shaft-condylar angle less than 40° and 2 elbows with more than 40°. In non-fracture group, there were 2 elbows with <40° of the angle and 27 elbows with more than 40° as shown in Table 2. Therefore, the accuracy was 92%, the sensitivity was 76%, the specificity was 93%, the positive predictive value was 92% and the negative predictive value was 93%.

For the LCHA, there were 24 elbows with value more than 50° and 8 elbows with <50° in the fracture group. In non-fracture group, there were 8 elbows with more than 50° of the angle and 21 elbows with less than 50°. Therefore, the accuracy was 70%, the sensitivity was 55%, the specificity

**Table 2** Demographic data and primary outcome results

Patient	Fracture group	Non-fracture group
Number	24	29
Age (years)	6.1 (2–15)	6.5 (2–15)
Male/Female	57.2%/42.8%	72.4%/27.6%
Average SCA (°)	33 (17–49)	46.75 (37–60)
Average LCHA (°)	57.04 (47–78)	50.45 (32–57)

was 72%, the positive predictive value was 67% and the negative predictive value was 72% (Table 3).

## Discussion

Supracondylar fractures are one of the most common fractures in children [1]. AP and lateral X-rays of the elbow are usually sufficient for diagnosis. Finding such as a posterior fat pad sign, displacement of anterior humeral line (AHL) and alteration of Baumann angle (BA) are clearly seen in complete fracture [7]. Unfortunately, Shrader et al. [8] reported that 47% of the true elbow fracture in children were neglected in emergency room, especially if the fracture had minimal displacement. Furthermore, Warmsley et al. showed that delaying in diagnosis and treatment more than eight hours increased the conversion rate to open surgery from 11.2 to 33%. In type III supracondylar fracture, Yildirim et al. [9] also reported that closed reduction was no longer possible after 32 h. Therefore, prompt diagnosis is required for satisfactory outcomes of the patient (Table 4).

In normal pediatrics' elbow, the AHL should traverse the capitellum in its middle third. Nevertheless, Herman et al. [10] claimed that the AHL did not bisect the middle third of capitellum in 49% of normal elbow. This variation also depended on age of patients which make diagnosis of supracondylar fracture of humerus more complicated and the uses of AHL alone for diagnosis may not sufficient. For the BA in anteroposterior radiographs of the elbow, Camp et al. [11] showed that this angle varies 6° for every 10° of humeral

**Table 3** Diagnostic accuracy of the SCA

SCA (°)	Fracture	Non-fracture	
< 40	22	2	
> 40	2	27	
Total	24	29	53
Sensitivity	76%		
Specificity	93%		
PPV	92%		
NPV	93%		

**Table 4** Diagnostic accuracy of the LCHA

LCHA (°)	Fracture	Non-fracture	
> 50	16	8	
< 50	8	21	
Total	24	29	53
Sensitivity	70%		
Specificity	55%		
PPV	67%		
NPV	72%		

rotation. We suspected that there should be other parameters which can aid in diagnosis of the supracondylar fracture, especially in an incomplete fracture.

In supracondylar fracture of pediatric elbow, the Gartland type II is the most controversial type due wide range of severity from minimal displace to nearly total displace. The decision for treatment has to be made case by case that leads to a variation in both management and outcome. Sinikumpu et al. [12] showed that type II fractures were associated with both satisfactory (57.7%) and unsatisfactory (42.3%) results. AHL is one of the most important parameters that guide the treatment in supracondylar humeral fracture type II. Iorio et al. [13] showed that the BA and the AHL are the most important parameter that can guide the treatment option. In the patient that the AHL bisects capitellum, conservative treatment can be done and good result can be expected. Kao et al. [14] showed that patients with the AHL that cross middle and posterior thirds of capitellum have better elbow range of motion. If the AHL crosses anterior one third of the capitellum, it is considered under reduction. However, in some groups of patients, the AHL can be dissected anterior one-third in normal elbow so the AHL alone may not sufficient for making a decision to treatment.

Madjar-Simic et al. [6] showed that the shaft-condylar angle consisted of longitudinal line of diaphysis of the humerus with the axial line of the condyle and is about 40° in the true lateral view of elbow. In our study from subjects with traumatic elbow injury without obvious displacement, we found that the accuracy, sensitivity, specificity, PPV and NPV of the shaft-condylar angle in diagnosis of supracondylar fractures are 92%, 76%, 93%, 92% and 93%, respectively. Although the sensitivity is moderated, the accuracy and specificity are quite high. Moreover, if the shaft-condylar angle is less than 40° in a suspected case, it is likely to be an incomplete extension type of the supracondylar fracture because of high-leveled positive and negative predictive values. As it is readily available in the lateral elbow film, this angle may represent as an additional option to assist in diagnosis of an incomplete supracondylar fracture in the patient that AHL dissects anterior thirds of capitellum with the SCA

less than 40°. The likelihood of this group of patient to be a displaced fracture is high, so close reduction or at least further investigation such as contralateral film is needed.

In this study, the measurement of the LCHA, which can also be done on lateral elbow film, was done. Although we founded that in fracture group LCHA was likely to be increased, the accuracy, sensitivity, specificity, PPV and NPV are quite low. Therefore, this angle may be not reliable.

There were some limitations of our study due to retrospective analysis of the data. Although we did not evaluate the inter- and intra-observer reliability of the measurement, Suangyanon et al. demonstrated good reliability of the shaft-condylar angle.

## Conclusion

Although the cut point of the shaft-condylar angle at 40° was not elevated in sensitivity, the specificity, accuracy, positive predictive value and negative predictive value were quite high. These findings implied that this test might be an accurate assessment to assist the physician to diagnose the incomplete fracture of the supracondylar area of the distal humerus in pediatrics patient with elbow injury.

## Compliance with ethical standards

**Conflict of interest** Pawaris Sukvanich, Peen Samun, and Pinkawas Kongmalai declare that they have no conflict of interest.

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