Injury, Int. J. Care Injured xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

# Clinical significance of anterior humeral line in supracondylar humeral fractures in children

Hsuan-Kai Kao, Wei-Chun Lee, Wen-E. Yang, Chia-Hsieh Chang*

*Department of Pediatric Orthopedics, Bone and Joint Research Center, Chang Gung Memorial Hospital, Chang Gung University, Taoyuan, Taiwan*

ARTICLE INFO

*Article history:*
Accepted 30 June 2016

*Keywords:*
Child
Elbow
Humeral fractures
Fracture fixation
Anterior humeral line

ABSTRACT

*Introduction:* Anterior humeral line (AHL) location is commonly used to evaluate sagittal alignment after fracture reduction in children with supracondylar humeral fractures. However, the position of the AHL for acceptable fracture reduction has not been validated by clinical outcome. The purpose of this study was to investigate the relationship between the location of AHL and range of elbow motion.

*Patients and methods:* We retrospectively reviewed 101 children who underwent closed reduction and percutaneous pinning for Gartland type III supracondylar humeral fractures between January 2009 and June 2014. There were 67 boys and 34 girls, with a mean age of 7 years. The children were classified according to the location of the AHL three months postoperatively into five groups: anteriorly loss (n = 6), anterior third (n = 25), middle third (n = 47), posterior third (n = 21), and posteriorly loss (n = 2). Range of elbow motion was measured by attending paediatric orthopaedic surgeons with a goniometer. Clinical and radiographic outcomes were compared among the five groups.

*Results:* The mean elbow extension angle was not significantly different among the groups ($p = 0.21$). However, children with AHL anterior to the capitellum had less elbow flexion angle (125.8° vs. 131.2°, $p = 0.046$) and less total range of elbow motion (128.3° vs. 135.7°, $p = 0.048$) than children with AHL crossing the capitellum. When the AHL crossed the capitellum, the elbow flexion angle and total range of elbow motion were significantly decreased in children with AHL crossing the anterior third of the capitellum. The Flynn criteria were not significantly different among the central three groups ($p = 0.131$). However, the Flynn criteria were significantly worse in children whose AHL missed the capitellum ($p < 0.001$). The mean Baumann angle measured 3 months postoperatively was not significantly different among the groups ($p = 0.12$).

*Conclusions:* These findings demonstrate that children with AHL crossing the middle and posterior thirds of the capitellum appear to have slightly better early elbow flexion and total range of elbow motion. AHL crossing the anterior third of the capitellum can be an underreduction that has similar elbow motion as AHL anterior to the capitellum. AHL posterior to the capitellum is a warning sign of overreduction and should be avoided.



## Introduction

Supracondylar humeral fractures are the most common elbow fractures in children [1,2]. The Gartland system is most often used for classification of these fractures [3]. Type I fractures are nondisplaced, type II fractures are hinged fractures with an intact posterior cortex and type III fractures are completely displaced. Surgical fixation is commonly recommended for Gartland type III fractures to prevent malunion [4–9].

Malunion with varus or hyperextension deformity of the elbow is fairly common after type III supracondylar humeral fracture. Cubitus varus is mostly cosmetic, but hyperextension deformity affects elbow function. The sagittal alignment of the reduction has not received the same attention as coronal alignment because hyperextension deformity was expected to be corrected with growth and remodelling. However, Simanovsky et al. reported that 77% of patients with an underreduced supracondylar fracture still showed radiographic abnormality until skeletal maturity, and 50% had limited elbow flexion [10].

In the sagittal plane, the anterior humeral line (AHL) was often used to assess the quality of reduction intraoperatively. It was suggested that the AHL should bisect the capitellum within its middle third [5,11,12]. This rule was based on radiographic

* Corresponding author at: Department of Pediatric Orthopedics, Chang Gung Memorial Hospital, No. 5, Fusing St., Gueishan Dist., Taoyuan City 33305, Taiwan.
*E-mail address:* chiahchang@gmail.com (C.-H. Chang).

http://dx.doi.org/10.1016/j.injury.2016.06.037
0020-1383/

measurements of normal elbow anatomy. However, position of the AHL for acceptable fracture reduction has not been validated by clinical elbow function. It is not reasonable to attempt perfect fracture reduction radiographically without real benefit in clinical function.

The purpose of the present study was to review children with Gartland type III supracondylar humeral fractures treated by closed reduction and percutaneous pinning to answer the following questions. (1) Does range of elbow motion decrease if AHL does not cross the capitellum? (2) If AHL crosses the capitellum, does range of elbow motion decrease when AHL crosses the anterior third of the capitellum? (3) What is the clinical outcome if AHL is posterior to the capitellum?

## Patients and methods

After approval by the institutional review board of the authors' hospital, we retrospectively reviewed medical records and radiographs of patients with paediatric supracondylar humeral fractures that presented between January 2009 and June 2014. The inclusion criteria were skeletal immaturity, older than 4 years of age, a Gartland type III supracondylar fracture and follow-up of more than 1 year. Children who had previous humeral fractures, flexion-type supracondylar fractures, and fractures requiring neurovascular exploration were excluded. In addition, we excluded children younger than 4 years of age because of the small size of the capitellum making measurements of anterior humeral line more challenging.

The study population consisted of 101 children, 67 boys and 34 girls, with a mean age of 7.1 years (range, 4–12.8 years). All of them had a Gartland type III supracondylar humeral fracture treated by closed reduction and percutaneous pinning. All children were treated by the attending paediatric orthopaedic surgeons or orthopaedic trauma surgeons within 24 h of arriving at the emergency department. The surgeons subjectively selected pin size, pin construct and number of pins at the time of surgery. After the operation, the children had clinical and radiographic follow-ups at 2 weeks, 4–6 weeks, 3 months, 6 months, and 1 year. The cast and K-wires were removed after fracture union in the outpatient clinic, usually 4–6 weeks later. No formal physical therapy program was administrated postoperatively.

The anterior humeral line (AHL) is a line drawn along the anterior cortex of the distal humerus on the lateral radiograph of the elbow. The capitellum is divided into three equal parts. The relationship between AHL and capitellum was classified as anteriorly loss (AL), anterior third (A), middle third (M), posterior third (P) and posteriorly loss (PL) (Fig. 1). Examples are provided in Fig. 2. The children were classified into five groups according to the location of AHL measured 3 months postoperatively: anteriorly loss (n = 6), anterior third (n = 25), middle third (n = 47), posterior third (n = 21), and posteriorly loss (n = 2) (Fig. 3). Age, gender, number of pins and duration of pin retention were not different among the five groups (Table 1).

Clinical outcomes, 3 months postoperatively, were assessed using the criteria of Flynn et al., based on the carrying angle and the range of elbow motion [13]. Range of elbow motion was measured by attending orthopaedic surgeons with a goniometer. For measuring elbow ROM, the goniometer was centered at the distal humerus to approximate the axis of elbow motion. The arms of the goniometer were aligned parallel to the axis of the humerus and the forearm. Then the elbow ROM was determined. A negative value of elbow extension represented hyperextension. Radiographic evaluation, 3 months postoperatively, included the Baumann angle on the anteroposterior radiograph and the location of the AHL on the lateral radiograph. The Baumann angle was measured between the line along the axis of the humeral shaft and the line along the capitellar physis on the anteroposterior radiograph [14–16].


**Fig. 1.** Anterior humeral line is formed by drawing a line along the anterior surface of the distal humerus. The line is continued distally and its relationship with the capitellum is recorded. The relationship between the AHL and capitellum is classified as anteriorly loss (AL), anterior third (A), middle third (M), posterior third (P), and posteriorly loss (PL).

Demographic data, including age, gender, duration of pin retention, preoperative associated injuries and postoperative complications were recorded. The postoperative complications that were recorded included pin migration, pin site infection requiring hospitalization, postoperative nerve palsy and the need for additional surgery were also recorded.

Demographic data and radiographic measurements were compared among the 5 groups. The Fisher's exact test was used to compare categorical data among the groups. For numerical data, one-way analysis of variance (ANOVA) was used for between-group comparisons. The Scheffe's method was used for post hoc comparisons. For the first question, the range of elbow motion in children with AHL anterior to the capitellum (group AL) were compared to the children with AHL crossing the capitellum (group A, P and L) using ANOVA. For the second question, range of elbow motion were compared among the children with AHL crossing the capitellum (group A, P and L) using ANOVA. The significance level was $p < 0.05$. Statistical analysis was performed with SPSS software (IBM Corp, version 20.0, Armonk, New York).

## Results

The mean elbow extension angle was not significantly different among the groups ($p = 0.21$). However, children with AHL anterior to the capitellum (group AL) had less elbow flexion angle (125.8°

Please cite this article in press as: H.-K. Kao, et al., Clinical significance of anterior humeral line in supracondylar humeral fractures in children, Injury (2016), http://dx.doi.org/10.1016/j.injury.2016.06.037