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Intraoperative assessment of Baumann's angle and carrying angles are very good prognostic predictors in the treatment of type III supracondylar humerus fractures in children

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Abstract: *Background:* In children supracondylar fracture of the humerus is one of the common fractures in first decade of life. Cubitus varus is the most common complication following supracondylar fractures in children irrespective of the method of treatment used. This study was conducted to establish the efficacy and the accuracy of intraoperative measurements of Baumann's and carrying angles in the final outcome of supracondylar fracture humerus in children. *Methods:* Twenty eight cases of Gartland's Type III supracondylar humerus fractures were treated with closed reduction and percutaneous crossed Kirschner wire fixation under image intensifier. Intra operatively Baumann's and carrying angles were measured and compared with the readings of the final follow up. The cases were followed up for an average period of 6 months. *Results:* The mean normal side Baumann's angle was 74.5^0 among boys and 73.4^0 among girls, the mean normal side carrying angle was 10.77^0 among boys and 14.3^0 among girls. The mean affected side Baumann's angle was 78.4^0 among boys and 79.1^0among girls; the mean affected side carrying angle was 8.77^0 among boys and 12.4^0 among girls at final follow up. There was no significant difference between the Baumann angle after reduction and that measured at follow-up. There was no case of cubitus varus deformity. *Conclusion:* Intraoperative assessment of Baumann's angle and carrying angles are very good and reliable factors in the treatment of type III supracondylar humerus fractures in children.

Keywords: Supracondylar fractures of humerus, Cubitus varus, Baumann's angle, Carrying angle

Introduction

Fractures around elbow joint represent approximately 10% of all pediatric orthopaedic injuries. Supracondylar fracture of humerus is the second most common fracture in children accounting for about 75% of all injuries around the elbow [1-2]. These fractures are most common serious elbow injuries and commonest upper extremity fracture in children associated with complications [3-4]. Supracondylar fractures are most common serious elbow injuries in children as the bony architecture at supracondylar region is weak and vulnerable because in this region:

(a) Bone is remodeling.
(b) It is flattened anteroposteriorly.
(c) Three fossae makes cortex thin.
(d) Anterior cortex has defect in area of coronoid fossa.
(e) Laxity of the ligaments permits hyperextension at the elbow.
(f) High sportive activity in children.

The treatment of these fractures continues to be a topic of discussion and controversy. Fracture peaking at 5-6 years old. It is more common in boys than girls. However, although the serious complications of forearm ischaemia and volkmann's contracture are fortunately rare, the other major complications of a supracondylar fracture and its treatment have included vascular compromise, compartment syndrome, neurological deficit, elbow stiffness, pin track infections, myositis ossificans, nonunion, osteonecrosis, loss of reduction, hyperextension, and cubitus varus malunion.

Cubitus varus remains the most common delayed complication of type III supracondylar humerus fractures, which is when complete displacement occurs with no cortical contact according to the Gartland's classification [4]. The accuracy of the initial reduction best predicts the incidence of subsequent deformity [5]. The outcome of

supracondylar fractures in this population has been commonly determined by clinical and radiographic parameters such as carrying angle and the Baumann's angle of the humerus [6].

Carrying angle: The carrying angle of the elbow is defined as the angle between the long axis of the extended and supinated forearm to the long axis of the arm [7]. The angulation is as a result of the configuration of the articulating surfaces of the humerus and ulna which produce a normal valgus angulation of the forearm in relation to the humerus. The medial flange of the trochlea of humerus is partly responsible as it projects nearly 6 mm below than the lateral edge and the obliquity of the superior articular surface of the coronoid process which is not set at right angles to the shaft of ulna. In the ulna a curved ridge joins the prominences of the coronoid and olecranon processes which fits the groove in the trochlea of the humerus. The obliquity of the shaft of ulna to this ridge accounts for most of the carrying angle at the elbow.

Clinically carrying angle increases with skeletal growth up to 15 years of age, after which there will be slight decrease in the angles. Potter [8] was the first to carry out a quantitative investigation on the carrying angle in man. The rate of carrying angle increment for boys and girls is 0.42 and 0.60 per year respectively [9]. The carrying angle apparently develops in response to pronation of the forearm and keeps the swinging upper extremity away from the side of the pelvis during walking, swinging, and carrying objects. However, the line of the upper arm and forearm becomes straightened out when the forearm is in the usual working position of almost full pronation.

Anatomically, the carrying angle in human adults is approximately 10^0 in men and 13^0 in women. The angle is usually greater in females than in males and the difference has been considered to be a secondary sexual characteristic as well as its role in the sex determination are long debated issues in anatomy and anthropology researches. Increased value of this angle in the female gender would be justified by the presence of ligamentous laxity [8] 'Carrying angle' theory is that the broad shoulders and narrow hips of male allows the arms to hang straight downwards, with long axis of the upper and lower segment approximately in the same straight line. Whereas in the female, the narrower shoulder and broader hips require a splaying out of the forearm axis in order that the hanging arms clear the hips. The angle is greater in the dominant limb than in the non-dominant limb of both sexes, suggesting that natural forces acting on the elbow modify the carrying angle. Developmental, ageing and possibly racial influences add further to the variability of this parameter.

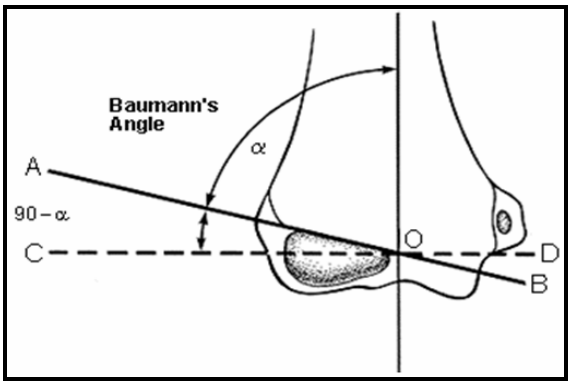
The knowledge of carrying angle is highly significant in the management of various types of fractures of the elbow. Increasing the carrying angle may lead to elbow instability and pain during exercise or in throwing activities of sports, may reduce function of elbow flexion, predispose to risk of elbow dislocation, increase evidence of elbow fracture when falling on the outstretched hand, fracture of the distal humeral epiphysis and entrapment neuropathy of the ulnar nerve at the elbow. Decreased carrying angle leads to cubitus varus deformity. Prevention of angulations depends on the accurate reduction of the fracture, the gold standard in clinical practice, today is an assessment of reduction quality intraoperative by measuring Baumann's angle and carrying angle.

Fig-1: Carrying angle

Baumann's angle: Dr. Ernst Baumann [10] while treating displaced supracondylar humeral fractures in children with closed reduction and olecranon overhead traction demonstrated that this angle is a useful indicator of the adequacy of reduction of a displaced supracondylar humeral fracture. Baumann's angle is formed by the intersection of a line drawn down the humeral axis and a line drawn along the growth plate of the capitellum of the elbow. This gives a measure of the residual post reduction displacement which should predict cubitus varus. This angle correlates closely with the carrying angle [11].

The mean Baumann's angle is $72^0 \pm 4^0$. It is expected to be less influenced by the radiographic technique, elbow position and rotation of the distal fragment. The Baumann's angle of the humerus is a simple, and reliable measurement that can be used for the determination of the outcome of supracondylar humeral fractures in paediatric population. Baumann has also described the relationship between two important angles, the Baumann's angle and the carrying angle. For every 5^0 change in the Baumann's angle leads to 2^0change in carrying angle

Fig-2: Baumann's angle [10]



In normal children the Baumann's angle is the same in both elbows and it has been suggested that a comparison between the injured and uninjured sides could be used to assess the accuracy of reduction. We therefore present a simple rule to define radiologically cases where reduction should be redone. The distal humerus in children has a diamond shaped olecranon fossa bounded on the lateral and medial side by very thin plate of the cortical bone that forms two thin pillars. Disruption of the pillars is the main cause of the rotation and tilt that leads to the cubitus varus deformity. The pathology can be objectively measured by the Baumann's angle. This has been found to be consistently relevant in predicting the varus deformity following the supracondylar fracture. A linear relation between the Baumann's angle and the carrying angle could have made the first predict the other. Even if the relation is non linear increase in the Baumann's angle will leads in to decrease in the carrying angle. Aims of this study were to define the relationship of the Baumann angle with carrying angle in the normal arm, and to determine if the Baumann's angle and carrying angle measured intraoperatively after reduction could be used to predict the final carrying angle with accuracy and predict the probability of high risk for cubitus varus and identify cases needing re-reduction.

Cubitus Varus: Cubitus varus or gunstock deformity as it is commonly known as the most common long-term complication of displaced supracondylar fractures in children irrespective of the mode of treatment [12], with an incidence ranging from 3% to 58% [13]. It is now widely accepted that cubitus varus after supracondylar fracture is not the result of growth disturbance but of malunion of the fracture. The deformity involves not only loss of coronal varus mal-alignment to make the distal forearm and hand deviate to the midline of the body, but also has recurvatum (hyperextension) deformation in the sagittal plane and internal mal-rotation deformity in the axial plane [14]. This does not correct with remodelling and is cosmetically unacceptable especially in girls in the developing country settings. It thus appears that, whatever treatment is chosen, it is essential to confirm an accurate reduction so that a normal carrying angle can be predicted with confidence.

The consequences of cubitus varus have included an increased risk of lateral condylar fractures, pain, tardy posterolateral rotatory instability, tardy ulnar nerve palsy, internal rotational malalignment, and poor cosmesis. Some children may develop posterior shoulder instability with a Bankart lesion. Finally, subluxation of the ulnar nerve and medial head of the triceps over the medial epicondyle can produce pain, snapping, and paresthesias.

With easy access of image intensifier, closed reduction and percutaneous pinning is the treatment of choice in displaced fractures of supracondylar region of humerus in children. A precise rule to define unacceptable reduction from the cubitus varus perspective in the immediate post reduction film can help precisely target re-reduction to the high-risk group thus increasing the efficiency of preventing this complication.

Material and Methods

This study is a prospective observational randomized & open study on patients admitted to the department of orthopedics in Al-Ameen Medical College, Vijaypur with Gartland's extension type III supracondylar humerus fractures in children. The complete data collected from patient's attendents in a specially designed case record form by history of illness and doing detailed clinical examination including carrying angle of the uninjured upper limb. Preoperatively two standard antero posterior and lateral X-rays on the injured and the normal elbow were taken, The fracture pattern and Baumann's angle assessed for uninjured side. Patients were selected based on inclusion and exclusion criteria.

Inclusion criteria:

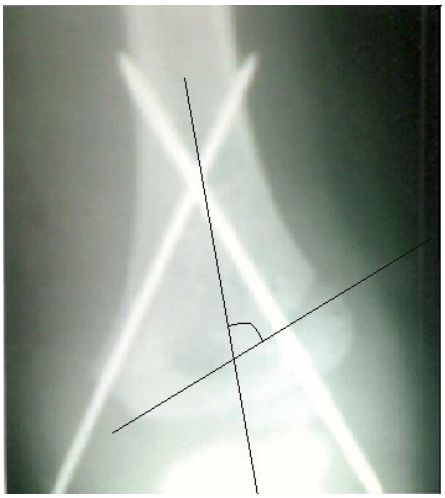
1) Children with closed extension type III supracondylar fractures humerus.
2) Patients aged < 10years.
3) Cases treated with closed reduction with crossed medical and lateral K-wire fixation.

Exclusion criteria:

1) Open supracondylar humerus fracture.
2) Age > 10 years.
3) Cases treated other than CRIF with crossed medial and lateral K-wire fixation.

Closed reduction with percutaneous crossed medial and lateral K-wire fixation done in all cases under image intensifier. Post reduction radiographs of the affected elbow anteroposterior and lateral view taken and adequacy of reduction were assessed by Baumann's angle of the affected side equaling or greater than that of the uninjured side. If more than 10^0 of difference compared to the uninjured side then re-reduction of the fracture done and always kept the difference to be less than 10^0 in comparison to opposite side. Carrying angle of the affected side measured as the elbow can be completely extended intraoperatively and is compared with the uninjured side.

Fig-3: Intraoperative assessment of Baumann's angle



The patient was observed for a period of 24 hours and was followed at 1 week, 3-4 week, 3 months and 6 months. Carrying angle and Baumann's angle and movements of elbow were assessed at each follow-up. Another set of radiographs were taken when the elbow attained full extension. An improvised instrument goniometer is used for measurement of carrying angle. Bicipital groove, biceps brachii tendon at its insertion and palmaris longus tendon at the wrist were palpated and marked as anatomical landmarks to demarcate the median axes of the arm and the forearm respectively for carrying angle assessment.

Results

A total of 28 patients included in the study, the minimum follow-up period was 3 months and followed for an average period of 6 months ranging from 3-9 months.

Demographic Characterstics: The overall study showed mean age of patients forming the study group was 5.96 years, majority of the patients were in the range of 4-8 years, youngest was 2 years and the oldest was 10 years, majority of patients were male accounting for 18 cases i.e 64.3%, the leading cause of injury was fall accounting for

78.57% of cases whereas road traffic accident accounts 21.43%. 11 cases occurred on right side and 17 occurred on left which is non dominant limb, there were 20 cases (71.42%) belonging to posteromedial (type III a) and 8 cases (28.58%) belonging to posterolateral (typeIII b) variety.

Carrying angle among males ranged from 9^0-12^0 valgus on the unaffected side and among females it ranged from 13^0-15^0 .The Baumann's angle in males on the unaffected and affected side ranged from 66^0 to 80^0 and 70^0 to 86^0 respectively, for the girls it was 72^0 to76^0 on the unaffected and 77^0 to 81^0 on the affected side. The mean normal side Baumann's angle was 74.5^0 among boys and 73.4^0 among girls, the mean normal side carrying angle was 10.77^0 among boys and14.3^0 among girls. The mean affected side Baumann's angle was 78.4^0 among boys and 79.1^0among girls, the mean affected side carrying angle was 8.77^0 among boys and 12.4^0 among girls at final follw up. The mean carrying angle of dominant side was 11.5^0 among boys and 14.4^0 among girls on un affected side and it is 8.58^0among boys and 12.4^0 among girls on the affected side.

Table-1: Comparison between Baumann's angle and carrying angle

	Mean CA		Mean BA		Dominant side CA	
	Unaffected	**Affected**	**Unaffected**	**Affected**	**Unaffected**	**Affected**
Boys	10.77^0	8.77^0	74.55^0	78.4^0	11.5^0	8.58^0
Girls	14.3^0	12.4^0	73.4^0	79.1^0	14.4^0	12.4^0

CA- Carrying angle,BA-Baumann’s angle

As the Baumann's angle increases, the carrying angle decreases, a 5^0 change in Baumann's angle continued to change in the carrying angle approximately 2^0. There was no significant difference between the Baumann angle after reduction and that measured at follow-up; and it is suggested that this angle after reduction can be reliably used to predict accurately the final carrying angle, so that cubitus varus deformity can be effectively prevented. It intends to correlate the Baumann’s angle to the final carrying angle of the injured elbow. There were no cases of cubitus varus deformity in our study and all fracture healed with almost near normal movements in all cases.

Discussion

The treatment of supracondylar humerus fractures in children continues to be controversial. Despite the numerous ways described of treating supracondylar fractures there will be complications of the fracture and its treatment. These includes vascular compromise, compartment syndrome, neurological deficit, elbow stiffness, pin track infections, myositis ossificans, nonunion, osteonecrosis, loss of reduction, hyperextension, and cubitus varus. Despite modern treatment techniques, cubitus varus remains a complication of type III supracondylar humerus fractures, which can only be prevented by achieving and maintaining an accurate reduction; this can be reliably assessed by comparing the Baumann’s angle and carrying angle on the injured and uninjured sides. Malunion is the most likely culprit for the greater majority of angular deformities, not growth disturbance, as there is very little growth in the distal humerus, and the deformity is present at the time of healing. The distal humerus malunion typically includes elements of varus, internal rotation, and hyperextension. The accuracy of the initial reduction best predicts the incidence of subsequent deformity.

The elbow is a highly congruent joint with a limited remodelling capacity. The final assessment of the reduction of a supracondylar fracture in children shows the importance of preventing any angular deformity of the elbow at the time of fracture reduction. Several angles could be measured on AP radiographs in order to allow determination of the degree to which the normal alignment of the elbow has been restored [15]. These measurements associated with some technical difficulties that lead to difficulty in fracture alignment assessment [16]. There is consensus that most important

measurement for assessment of the fracture reduction is the Baumann's angle [15] and satisfactory reduction based on carrying angle and Baumann's angle assessed in an operating room were good predictors.

The acceptance of inadequate reduction is partly due to the great difficulty of assessing the clinical carrying angle in the flexed elbow, it is also difficult to obtain adequate antero posterior radiographs when the elbow is in this position. The high incidence of cubitus varus after open reduction and internal fixation and after closed reduction and percutaneous pinning [17] suggests that a reliable radiological method of assessing reduction is essential.

The aim of treatment of these difficult fractures is to achieve a normal carrying angle with full function of the elbow and forearm. Direct assessment of the carrying angle before union of the fracture is only possible if the method of treatment is either traction in extension or internal fixation with early mobilization. The procedure of choice which can allow the full extension and supination of the elbow intra-operatively is used. Closed reduction with percutaneous crossed medial and lateral K wire fixation is the procedure of choice which allows the complete extension and supination of the elbow intraoperatively. Other procedures like closed reduction and posterior slab application will not allow the extension of the elbow and also the other methods.

The outcome of supracondylar humeral fractures in the paediatric population has been commonly assessed by clinical and radiographic parameters, including the Baumann angle of the humerus [18]. In an attempt to explain the wide range in the normal value of the Baumann angle, multiple factors that could affect both the anatomy of the distal portion of the humerus as well as the physical measurement of the Baumann angle have been investigated. Keenan and Clegg, after examining the radiographs of 577 paediatric elbows, performed an analysis of variance that suggested that neither age, gender, nor side measured affected the Baumann angle of the humerus [19]. The carrying angle at the elbow is assessed conventionally with the elbow in full extension using a protractor goniometer to measure the axes from the surface margin of the arm and forearm. We measured the carrying angle of the elbow through identification of bicipital groove, biceps brachi tendon insertion and Palmaris longus tendon which are considered as anatomical landmarks to identify median axis of arm and forearm respectively. Our data confirms a greater carrying angle in females than in males [20].

This finding is consistent with those of a normative study of carrying angles in children [9], which showed gender differences in carrying angles seemed to increase gradually with a maximum being around puberty and the carrying angle is greater in girls than in boys by a mean of 1.31. greater in females than in males and this difference is considered as a secondary sexual characteristic.[8] The variables like height of the individual, length of the arm and width of the hip are not influencing the carrying angle. The result of this study is useful in the management of type III supracondylar humerus fractures in children.

The present study clearly shows the direct relationship of the Baumann angle to the carrying in the normal arm. The measurement of this angle in a supracondylar fracture after reduction can thus be reliably used to predict the final carrying angle of arm. This study also confirms that there is no significant growth disturbance after these fractures, and that the Baumann's angle did not significantly alter during the follow up period.

Conclusion

Intraoperative assessment of Baumann's angle and carrying angles of the injured limb will reliably predict the final carrying angle and helps in decreasing the incidence of cubitus varus deformity. It helps in identifying the cases needing re-reduction intraoperatively and correcting at that time only.

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