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SUPRACONDYLAR HUMERAL FRACTURES IN CHILDREN

Causes of Changes in the Carrying Angle of the Elbow

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It is a well-known fact that exact reduction of a fracture is not always necessary in children, because growth may correct a deformity. Injury to the epiphysis, on the other hand, may lead to growth disturbance. In the present study the effect of growth on deformities resulting from supracondylar humeral fractures in children was evaluated in a clinical series.

MATERIAL AND METHODS

Follow-up examinations were performed in 151 patients who had sustained supracondylar fracture of the humerus during the period when they were children 1947-1958. Their mean age at the time of fracture was 7 years (range 2-13 years). The age group 5-9 years was represented by 66 per cent. The follow-up period ranged from 12 to 23 years, the mean being 15 years, and comprised the entire post-traumatic growth period in all cases. There were 100 male and 51 female patients. The fracture was located to the right in 51 cases, to the left in 100.

The following observations were drawn from radiographs:

1. The presence or absence of primary dislocation (D+ or D-).
2. Extension of the fracture to the epiphyseal plate.
3. Alignment achieved by reduction: possible changes in the carrying angle, either increase or decrease, as well as malrotation. The alignment was evaluated on the basis of the changes seen in the fracture line.
4. At follow-up the lateral angle between the length axis of the humerus and the tangent of its distal joint surface was measured on the antero-posterior films. The difference noted in this so-called "humerotangential-angle" (Harbauer 1958) between the fractured and intact sides was recorded as a change in the carrying angle.

RESULTS

Follow-up examination showed that the carrying angle on the injured side was the same as on the intact side in 80 patients, larger in 10 and smaller in 61. The angle was increased by 5 degrees in 5 patients, and

by 10 degrees in another 5. The decrease of the carrying angle was of 5 degrees in 21 patients, of 10 degrees or more in 40 patients (of 10 degrees in 22, of 15 degrees in 9, of 20 degrees in 5, and of 25 degrees in 4). An enlargement of the carrying angle always implied true cubitus valgus, whereas its diminution in 15 cases meant that cubitus valgus was slighter than on the intact side, in 29 cases that the patient showed cubitus rectus, and in 17 cases that the patient showed true cubitus varus. The relationship between the end result, on the one hand, and the primary dislocation and the result of reduction, on the other, appears in Table 1.

Table 1. Relationship between final carrying angle and primary dislocation and result of reduction.

	Final carrying angle		Total
	Symmetric with the intact side	Increased or decreased	
No primary dislocation			
Alignment preserved after immobilization	53	15	68
Alignment deteriorated during immobilization*	—	10	10
Primary dislocation present			
Alignment achieved by reduction	18	6	24
Alignment not achieved by reduction	9	40	49
Total	80	71	151

* Diminution of the angle in all cases.

The group showing changes in the carrying angle as the end result (71 patients) largely constituted cases in which exact alignment had not been achieved by reduction, or an initially perfect alignment had deteriorated during immobilization (50/71). The relationship between the result of reduction and the end result in these 50 cases is shown in Table 2.

A dislocation remaining after reduction showed the same direction

Table 2. Relationship between end result and type of deformity remaining after reduction.

Result of reduction	End result		Total
	Decrease of the carrying angle	Increase of the carrying angle	
Decrease of the carrying angle			
No rotation deformity	22	—	22
Rotation deformity present	17	—	17
Total	39	—	39
Increase of the carrying angle			
No rotation deformity	1	5	6
Rotation deformity present	1	1	2
Total	2	6	8
Rotation deformity only	3	—	3
Total	44	6	50

as the final deformity in the majority of cases (45/50). This correlation was not affected by the rotational displacement.

On the other hand, a rotation deformity remaining after reduction (31 patients) was at the same time associated with a decreased carrying angle in 17/31 patients and with a final decrease of this angle in 21/31 patients.

In spite of deformity remaining after reduction, the end result was symmetric with the other side in 9/59 patients (Table 1). In 8 of these cases only a rotation deformity remained after reduction. In one case a slightly increased cubital angle and a rotation deformity had remained. This means that in 1/48 cases a tilting deformity after reduction led to normal carrying angle.

Growth Disturbance

As may be seen in Table 1, an initially undislocated or exactly reduced fracture, which had remained in alignment, resulted in the development of a change in the carrying angle in 21/92 patients. An

enlargement of this angle by 5 degrees was present in 4 cases, whereas 17 showed its diminution. In the latter there was a decrease of 5 degrees in 9 patients, of 10 degrees in 6 and of 15 degrees in 2. Two patients showed true cubitus varus, 8 showed cubitus rectus, and 7 showed a decrease of the normal cubitus valgus.

The extension of the fracture into the epiphyseal plate and the effect of age were studied from the viewpoint of a possible association with growth disturbance. Instead of chronological age, epiphyseal age was used, the patients being classified into seven groups on the basis of the following radiographical criteria (Grashey & Birkner 1953):

Group 1 = only the radial epiphysis of the distal end of the humerus visible.

Group 2 = the epiphysis of the capitulum radii also visible.

Group 3 = the epiphysis of the ulnar epicondyle of the humerus has become visible.

Group 4 = the epiphysis of the olecranon is also distinguished.

Group 5 = the ulnar epiphysis of the distal end of the humerus (the trochlea) has become visible.

Group 6 = the epiphysis of the radial epicondyle of the humerus is also seen.

Group 7 = the epiphysis of the radial epicondyle has fused with the radial distal epiphysis of the humerus.

The final results in the patients with perfect alignment at the stage of immobilization are shown in Table 3 according to epiphyseal age groups. The possible extension of the fracture into the epiphyseal plate on radial or ulnar aspect is also indicated. The analysis of Table 3 showed that no significant correlation could be demonstrated between the development of a deformed carrying angle and the growth stage in which the fracture was sustained, although the growth deformity was most usual in the epiphyseal age group 3. On the other hand, an abnormal carrying angle developed significantly more often in the patients showing a fracture line extending into the epiphyseal plate (14/17) than in the remainder (7/75) (Table 4).

In all of the 4 cases in which an enlargement of the carrying angle developed, the fracture line extended into the radial epiphyseal plate. As regards the patients with a diminution of the carrying angle, 10/17 had fractures extending into the epiphyseal plate, the radial and ulnar epiphyses being equally often involved.

In addition to the fractures extending into the epiphysis shown in

Table 3. End results in patients with perfect alignment at the final stage of immobilization, classified according to epiphyseal age. Extension of fracture into the epiphyseal plate is indicated.

Epiphyseal age group	Final carrying angle compared to the intact side						
	Symmetric		Changed				Total
	Fractures extending into epiphyseal plate radial	ulnar	Total	Fractures extending into epiphyseal plate radial	Decreased ulnar	Increased Fractures extending into epiphyseal plate ulnar	
1	1	-	11	1	-	-	-
2	-	-	8	1	-	-	-
3	1	-	20	2	3	-	2
4	-	-	6	1	-	-	-
5	-	-	17	-	1	-	2
6	-	-	7	-	1	-	-
7	1	-	2	-	-	-	-
Total	3	-	71	5	5	4	4

Table 4. Relationship between end result and extension of fracture into the epiphyseal plate in patients with perfect alignment at the final stage of immobilization.

Extension of fracture into epiphyseal plate	Final carrying angle compared to the intact side		Total
	Symmetric	Changed	
—	68	7	75
+	3	14	17
Total	71	21	92

Table 4, the series comprised 5 patients with similar fractures. In 4 of these a decreased carrying angle remained after reduction, and a similar deformity was also noted as the end result. In one case an increased carrying angle without any malrotation remained after reduction, but a decreased angle was noted as the end result.

DISCUSSION

In supracondylar humeral fractures in children it is considered difficult to predict the end result in terms of the final carrying angle, because evaluation of the alignment of the fragment on antero-posterior films is a problem (Smith, L. 1960). The angulations can be erroneously projected for technical reasons. In the present series an abnormal angulation corresponding to the final deformity was however distinguished in most cases (45/71) already after reduction. In 1/48 cases did a tilting deformity after reduction lead to normal carrying angle. These observations argue in favour of the view that tilting of the distal fragment remaining after reduction is the most important cause of changes in the carrying angle (King & Secor 1951, Mann 1963, El-Sharkawi & Fattah 1965, Smith 1960), and that this deformity is not corrected by growth (Avellan 1933, Mann 1963, El-Sharkawi & Fattah 1965). Medial or lateral dislocation of the distal fragment (Aitken et al. 1943) and a rotation deformity of this fragment (Aitken et al. 1943, Madsen 1955, French 1959) have also been mentioned as causes of changes in the carrying angle. However, it seems unlikely that these deformities as such would necessarily alter this angle, but they may cause instability of the fragment and thus provoke tilting (Smith 1960). The effect of a rotation depends on whether it has oc-

curred in a transverse or oblique fracture. In the latter case rotation causes tilting, the degree of which can be directly calculated (tilting in degrees = rotation in degrees : $180 \times$ the slope of the fracture surface in degrees $\times 2$). In our series the rotation deformity remaining after reduction was mostly (17/31) concomitant with a tilting of the distal fragment to the direction of a decreased carrying angle.

Growth disturbance has also been mentioned as a possible cause of deformity of the carrying angle following supracondylar humeral fractures in children (Siris 1939, Brewster & Karp 1940, Høyer 1952, Madsen 1955, Cave 1958, Smith 1967), although this is considered an uncommon etiology (Smith 1960). Growth disturbance can be blamed for the change in the carrying angle only if a definite increase of the deformity can be observed during the growth (Langenskiöld & Kivilaakso 1967). In our series 15 undislocated and 6 exactly reduced fractures led to a change in the carrying angle during the growth. In 13 of these cases there was a deviation of only 5 degrees. This change of the cubital angle on the injured side was observed both radiographically and clinically in all patients. Our observations are evidence in favour of the view that growth disturbances altering the cubital angle occur as result of supracondylar humeral fractures in children, even in cases initially showing no dislocation (Siris 1939). The growth disturbance is usually interpreted as retardation of the growth of the trochlea or the capitulum of the humerus, resulting in valgus or varus deformity, respectively (Siris 1939, Høyer 1952, Cave 1958, Smith 1967), but some authors are of the opinion that a fracture may stimulate the growth of the trochlear epiphysis (Brewster & Karp 1940, Aitken et al. 1943, Blount 1955). According to Siris, growth is retarded precisely in cases showing extension of the fracture through the epiphyseal plate into the epiphysis. In our series growth disturbance was significantly related to extension of the fracture line into the epiphyseal plate. The general opinion is that fracture of the epiphyseal plate may retard growth by ossification of the fissure traversing that plate (Salter & Harris 1963). However, in the present series it seems obvious that extension of the fracture into the epiphyseal plate did not invariably have this effect. In some cases it must be assumed that it had a growth-stimulating effect. It might also be that the extension of the fracture into the epiphyseal plate was not an essential factor in these cases; some other property of the fracture, perhaps its vicinity to the epiphyseal plate as such, may have affected the growth. It is known that metaphyseal fractures may have a growth-stimulating

effect in children. However, this phenomenon does not seem to be fully understood, and the results of experimental acceleration of growth are uncertain (Ingram 1963).

SUMMARY

This is a report on follow-up examinations of 151 supracondylar humeral fractures in children. The follow-up time comprised the total post-traumatic growth period. Changes in the carrying angle were in most cases attributed to tilting of the distal fragment, remaining after reduction. Growth disturbance may cause corresponding changes even in initially undislocated fractures. Extension of the fracture into the epiphyseal plate increases the risk of the late deformity resulting from growth disturbance.

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