Coll. Antropol. **38** (2014) 2: 601–604
Original scientific paper

Bone Remodeling after Supracondylar Humeral Fracture in Children

Harry Nikolić[1], Nado Bukvić[1], Zlatko Tomašić[1], Ana Bosak[1] and Tedi Cicvarić[2]

[1] University of Rijeka, University Hospital Center Rijeka, Department of Pediatric Surgery, Rijeka, Croatia
[2] University of Rijeka, University Hospital Center Rijeka, Department of Traumatology, Rijeka, Croatia

A B S T R A C T

The aim of this study was to evaluate bone remodeling in treated supracondylar humeral fractures in children. The study was carried out at the Department of Pediatric Surgery of University Hospital Rijeka on 58 patients with an average of 6.2 years, followed up during 1 to 7 years. The Baumann angle of the humerus was measured by five observers on the anteroposterior radiographs of the injured elbow right after the surgery, and on routine follow-up. The results obtained were compared with the results of the Baumann angle on the healthy arm, and statistically processed. There was a significant difference in number of cases that showed an increase of Baumann angle, when related to cases with no change of the angle or its decrease. The mean value change of Baumann angle in cases of its increase was 4.22° and in cases of its decrease 2.65°. Because of relatively low mean values of the angles of remodelation, we concluded that an adequate reduction is essential to prevent malunion in supracondylar humeral fractures.

***Key words**: bone remodeling, Baumann angle, child, supracondylar humeral fracture*

Introduction

Supracondylar fracture of the humerus is a common elbow injury in children. Two thirds of all hospitalizations for elbow injuries in children are for supracondylar fractures[1]. They are categorized as extension or flexion injuries. The extension type is more common, accounting for 90% to 98% of cases. It is caused by falling on an outstretched arm[2]. The modified Gartland classification of supracondylar humeral fractures is the most commonly accepted and used classification system[3]. In this system type I fractures are nondisplaced. Type II fractures are displaced with a variable amount of angulation, but the posterior cortex of the humerus is intact. Type III fractures are completely displaced with no cortical contact. Type IV fractures are characterized by an incompetent periosteal hinge circumferentially, and are defined by instability in flexion and extension.

The radiographic examination of the injured elbow must include anteroposterior and lateral view. Baumann angle has been validated as one of the most reliable parameters in radiologic monitoring of displaced supracondylar fractures of the humerus in children. This angle is created by the intersection of a line drawn down the humeral axis and a line drawn along the growth plate of the lateral condyle of the elbow[4,5] (Figure 1). It has been found to range from 64–81°, increases slightly with maturation and has no sex variation. Baumann angle of the contralateral elbow should be used for comparison[6]. Baumann angle has been found to usually vary <2° from the opposite side, so this can be used as a guide to correct the angle at which to maintain the injured arm[7].

After clinical and radiological assessment and classification of the supracondylar humeral fracture the decision is made about the type of treatment. The treatment can be performed, depending on the type of treatment, by immobilization of the elbow in a comfortable position of flexion, traction, closed reduction and pin fixation or by open reduction[3,8]. The right type of treatment, good operative technique, as well as postoperative care is main conditions of establishment of appropriate anatomical shafts of humerus and avoidance of *cubitus varus*[9]. Results of different types of treatment of supracondylar humeral fractures as well as operative techniques that are applied are well described and have already been known[10–12]. In majority of those papers bone remodeling is just mentioned but without correct analysis of its role and effect on treatment results.

Received for publication September 19, 2010

Fig. 1. Anteroposterior radiograph of the injured elbow after the surgery. The Baumann angle was measured using the AutoCAD package program by drawing a line perpendicular to the longitudinal axis of the humeral shaft, and a line following the physeal line of the lateral condyle.

The aim of this paper was to determine the amount of bone remodeling in treated supracondylar humeral fractures.

Patients and Methods

The study included 58 patients with supracondylar fracture of the humerus treated between 1990 and 2007. There were 18 girls and 40 boys involved, age ranging from 2 to 9 years, with an average of 6.2 years. In 56 of the cases they were extension fractures, only in 2 cases flexion type of fracture. The criteria for the inclusion in the study were clinical and radiological evidence of various grades of supracondylar fracture of the humerus of one arm. In 22 cases the fracture was second grade and in 36 cases third grade classified by Gartland. The criteria for exclusion were previous supracondylar fracture of the humerus of the same or the contralateral arm. Our patients were followed up during 1 to 7 years, or 3.9 years on the average. All of the treatment and surgeries were performed by a team of well experienced surgeons using the same surgical technique under the same conditions. All patients received adequate postoperative rehabilitation as well. Depending on the age of patients, an informed consent for participation in the study was obtained from the patient and their parents.

Clinical evaluation

During the clinical examination we evaluated the entire extremity, as forearm fractures can occur in association with supracondylar fractures and can substantially increase the risk of compartment syndrome. We especially took note of soft-tissue swelling, vascular and neurologic status of the arm.

Radiology

Radiographic examination begins with an anteroposterior and a true lateral radiograph of the elbow. Oblique views may be necessary to visualize minimally displaced fractures. X-rays of the injured elbow were made on the day of injury, right after the surgery and on routine follow-up. Identical X-rays of the healthy elbow were done in each patient at the time of the last follow-up for possible comparison. All radiographs were taken by an experienced technitian, following standard techniques. The Baumann angle was measured using the AutoCAD package program by drawing a line perpendicular to the longitudinal axis of the humeral shaft, and a line following the physeal line of the lateral condyle[13,14]. It was measured on the anteroposterior radiographs of these 58 elbows by five observers. Mean value of every single Baumann angle was taken as a value of comparison. All observers received specific instructions on how to measure the angle in order to ensure a standardized technique. All radiographs were presented to the observers in a random fashion, blinding any identifying patient information.

Statistical analysis

The Student t-test for paired samples was used to compare mean Baumann angles of traumatized and healthy arms on the follow-up examination, the Student t-test for independent groups was used to compare mean values of changed values of Baumann angle in cases of increase or decrease of the angle. The Kolmogorov-Smirnov test shows that the results of the distributions tested are normal (Traumatized arm after trauma: KS-Z=0.83; $p>0.05$; Traumatized arm on follow-up: KS-Z=1.34; $p>0.05$; Healthy arm: KS-Z=1.25; $p>0.05$). χ^2-test was used to compare frequencies. A p-value of less than 0.05 was considered significant. All statistical analyses were performed with the Statistica 7.1 statistical package (StatSoft Inc., Tulsa, OK, USA).

Results

Closed reduction and splint immobilization were done in 12 patients, 44 patients received closed reduction, Kirschner wire fixation and splint immobilization, and in two patients an open reduction, Kirschner wires fixation and splint immobilization was made.

By comparing the values of Baumann angle on the last follow-up of the humerus of the injured arm to the values of the contralateral healthy arm we found a difference. Baumann angle of the injured arm had signifi-

TABLE 1
COMPARISON OF THE VALUES OF BAUMANN ANGLE OF THE INJURED AND HEALTHY ARM (IN DEGREES) AT THE TIME OF LAST FOLLOW-UP

	N	$\overline{X}$±SD	t	df	p
Baumann angle of the injured arm	58	76.45±5.06	2.36	57	0.022
Baumann angle of the healthy arm	58	74.83±2.57			

TABLE 2
VARIATIONS OF THE BAUMANN ANGLE VALUES OF THE INJURED ARM BETWEEN OPERATIVE TREATMENT AND THE LAST FOLLOW-UP

	N	$\chi^2(2)$	p
Increase of the Baumann angle	36		
No change of the Baumann angle	5	25.28	<0.001
Decrease of the Baumann angle	17		

TABLE 3
COMPARISON OF THE MEAN VALUES OF THE CHANGED VALUES OF BAUMANN ANGLE IN CASES OF ITS INCREASE OR DECREASE (IN DEGREES)

	N	$\overline{X}$±SD	t	df	p
Increase of Baumann angle	36	4.22±3.83	7.09	51	<0.001
Decrease of Baumann angle	17	2.65±1.58			

cantly higher values (Table 1). Measured values of the Baumann angle of the humerus showed difference between the last follow-up and right after operative treatment. There was a significant difference in number of cases that showed an increase of Baumann angle when related to cases with no change of the angle or its decrease (Table 2). We also found the mean value of the changed Baumann angle to be significantly greater when the angle was increased than in cases of its decrease (Table 3). The results of change of the Baumann angle of the injured arm at the time of the last follow-up when compared to the measured values after the operative treatment were divided in two groups. Those cases that showed ideal or almost ideal value as the Baumann angle of the healthy arm were marked as good direction remodeling, and were placed in group one. Group two comprised those cases that showed moving away from an ideal value of the Baumann angle of the healthy arm, and were marked as bad direction remodeling. Number of cases that showed good direction remodeling (N=38) was significantly greater than bad direction remodeling (N=15), $\chi^2(1)=9.98$; p=0.002.

Discussion and Conclusion

Supracondylar humeral fractures are the most common elbow fractures seen in children. Modern techniques for their treatment have dramatically decreased the rates of malunion and compartment syndrome[3]. The pathogenesis of angular deformities of the elbow after supracondylar fractures of the humerus has not been clear yet. Some authors believed that rotation or medial tilting of the distal fragment or both, are responsible for the deformity whereas others thought that growth disorders of the cartilaginous complex of the distal end of the humerus induced by the fracture itself may cause it[15].

Our aim was to determine whether there is bone remodeling in treated supracondylar humeral fractures. The results of 58 supracondylar humeral fractures in children who in the time of injury and during the follow-up had an open physeal line of the lateral condyle were studied. It was possible to precisely follow postoperative values of Baumann angle of the distal humerus as the result of bone remodeling. Baumann angle of the humerus is a simple, repeatable and a reliable measurement that can be used for the determination of the outcome of supracondylar humeral fractures in the pediatric population[14]. Because of that the Baumann angle of the humerus has been commonly used as an outcome measure for supracondylar fractures in children. Because standard Baumann angle has range of 17°, in the questioned group of patients only one arm was injured and Baumann angle of uninjured humerus was used as normal value. Using this method we have measured the change in Bauman angle as a deviation from normal, uninjured humerus. We consider bone remodeling as the change of the axis between two fractured fragments after the healing with the purpose of reestablishing bone axis before the fracture[16]. It has been stimulated by activity of the osteoblasts and osteoclasts, that is by ossification and bone resorption at the place of the fracture. The main source of these cell actions are periosteum and endosteum. There is also an important influence of the age of the patients because of the wide periosteum in children[17]. Bone remodeling at the place of fracture is also dependant on the type, position of fragments and the distance between the fracture and the growth plate. Functional load of the extremity and the direction of the muscle traction on the fractured bone axis influence bone remodeling as well[18]. Therefore an ideal reduction of the fracture is not always necessary to make the final result of the treatment good. It is known that in children an angle of 15° can be tolerated between fragments of distal radius because with time due to remodelation there will be a complete correction of the bone axis[19].

Values of the Baumann angle on the last follow up and on the healthy arm of our patients showed significant in-

crease of the Baumann angle. These results correlate with the known fact of more frequent appearance of *cubitus varus*, although in different share, in all types of treatment of supracondylar humeral fracture[15]. Compared values of Baumann angle right after the surgery and on the last follow-up showed that in significant number of cases there was an increase of the angle when related to the number of cases when it was decreased or when there was no change of the angle. That shows that bone remodeling has greater potential towards development of *cubitus varus*. The results also showed that the remodeling caused nearing and moving away of the Baumann angle axis of the injured arm from the one on the healthy arm. Although there was nearing to the ideal axis of the Baumann angle of the healthy arm in significantly larger number of cases, mean values of Baumann angle's axis shift are low when compared to the width of normal Baumann angle range values of 17°. Also, if we consider that in five cases there was no change in Baumann angle we conclude that the value of remodelation after supracondylar humeral fracture is weak.

We should probably look for reasons of weak remodelation in the principles of growth of the upper extremity as well as on the fact that the distal part of the humerus provides only 20% of the growth of the humerus. The upper limb grows approximately 10 cm during the first year of life, 6 cm during the second year, 5 cm during the third year, 3.5 cm during the fourth year, and 3 cm during the fifth year[3,20]. Considering that, a child who is eight to ten years old has only 10% of growth of the distal part of the humerus remaining. Therefore we recommend, besides the grouping based on open epiphyseal plate, the distribution of patients considering expected humerus growth which would provide more precise value of remodeling when treating supracondylar fractures.

The results of this study showed that there was bone remodeling after treated supracondylar humerus fractures. However, because of the relatively low mean values of the angles of remodelation, its potential influence on the correction of the humeral axis is weak. Therefore we conclude that an adequate reduction is essential to prevent malunion in supracondylar humeral fractures.

REFERENCES

1. WILKINS KE, Fractures and dislocations of the elbow region. In: ROCKWOOD CA JR, WILKINS KE, KING RE (Eds) Fractures in Children (Lippincott, Williams and Wilkins, Philadelphia, 1991). — 2. MINKOWITZ B, BUSCH MT, Orthop Clin North Am, 25 (1994) 581. — 3. OMID R, CHOI PD, SKAGGS DL, J Bone Jt Surg Am, 90 (2008) 1121. — 4. WORLOCK P, J Bone Jt Surg, 68 (1986) 755. — 5. WILLIAMSON DM, COATES CJ, MILLER RK, COLE WG, J Pediatr Orthop, 12 (1992) 636. — 6. OTSUKA NY, KASSER JR, J Am Acard Orthop Surg, 5 (1997) 19. — 7. KENAN WNW, CLEGG J, J Pediatr Orthop, 16 (1996) 97. — 8. HAVLAS V, TRC T, RAJINDER G, SCHEJBALOVA A, J Pediatr Orthop, 28 (2008) 660. — 9. IPPOLITO E, J Bone Joint Surg Am, 72 (1990) 757. — 10. OSTOJIĆ Z, PRLIĆ J, JUKA K, LJUBIĆ B, ROTH S, BEKAVAC J, Coll Antropol, 34 (2010) 239. — 11. VUČKOV Š, KVESIĆ A, REBAC Z, CUCULIĆ D, LOVASIĆ F, BUKVIĆ N, Coll Antropol, 25 (2001) 255. — 12. LEKŠAN I, NIKOLIĆ V, MRČELA T, LOVRIĆ I, KRSTEK J, SELTHOFER R, Coll Antropol, 31 (2007) 1009. — 13. KIM WY, CHANDRU R, BONSHAHI A, PATON RW, Injury, 34 (2003) 274. — 14. SILVA M, PANDARINATH R, FARANG E, PARK S, CANADA C, FONG YJ, PENMAN A, Intern Orthop, 34 (2010) 353. — 15. IPPOLITO E, CATERINI R, SCOLA E, J Bone Joint Surg Am, 68 (1986) 333. — 16. ULSTRUP AK, Acta Orthop Belg, 74 (2008) 291. — 17. KONTULAINEN S, SIEVÄNEN H, KANNUS P, J Bone Min Res, 18 (2003) 352. — 18. FROST H, Angle Orthod, 64 (1994) 175. — 19. HOVE LM, BRVOVIC C, Arch Ortop Trauma Surg, 128 (2008) 55. — 20. DIMÉGLIO A, Growth in pediatric ortopaedics. In: Morrissy RT, Weinstein SL (Eds) Lovell and Winter´s pediatrics ortopaedics (Lippincott, Williams and Wilkins, Philadelphia, 2005).

H. Nikolić

University of Rijeka, University Hospital Center Rijeka, Department of Pediatric Surgery, Istarska 43, 51000 Rijeka, Croatia
e-mail: hnikolic@kbc-rijeka.hr

KOŠTANA REMODELACIJA NAKON SUPRAKONDILARNOG PRIJELOMA HUMERUSA U DJECE

SAŽETAK

Cilj istraživanja bio je procijeniti značaj koštane remodelacije liječenih suprakondilarnih prijeloma u djece. Istraživanje je provedeno na Zavodu za dječju kirurgiju Kliničkog bolničkog centra u Rijeci na 58 pacijenata prosječne dobi 6,2 godine praćenih kroz 1–7 godina. Pet promatrača mjerilo je Baumannov kut humerusa na anterioposteriornim rendgenskim snimkama ozlijeđenog lakta odmah po kirurškom liječenju i na rutinskim kontrolama. Prikupljeni rezultati uspoređivani su s vrijednostima Baumannovog kuta zdrave ruke te statistički obrađeni. Nađena je značajna razlika u broju slučajeva koji su pokazali povećanje Baumannovog kuta naprama onim slučajevima bez promjene ili s njegovim smanjenjem. Srednja vrijednost promjena Baumannovog kuta u slučajevima njegovog porasta bila je 4,22°, a u slučajevima njegova smanjenja 2,65°. Zbog relativno malih srednjih vrijednosti kutova remodelacije zaključili smo da je odgovarajuća repozicija nužna za sprječavanje lošeg srastanja suprakondilarnih fraktura humerusa.