

Effect of fracture location on rate of conversion to open reduction and clinical outcomes in pediatric Gartland type III supracondylar humerus fractures

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ABSTRACT

BACKGROUND: Supracondylar humerus fractures are the most common form of elbow fracture in children and adolescents. At present, treatment planning is based on the Gartland classification. Reduction and percutaneous pinning are done for Gartland type III fractures. In cases where closed reduction is unsuccessful, the procedure is converted to open reduction. However, there is no consensus on which patients are more likely to require conversion to open reduction. The aim of this study was to investigate the effect of fracture location on the rate of conversion to open reduction and clinical outcomes.

METHODS: A total of 112 patients who underwent early surgery for Gartland type III supracondylar humerus fracture between August 2011 and August 2017 were evaluated. The patients' age, sex, fracture location, post-operative loss of reduction, and complications were noted. The fractures were classified according to fracture level relative to isthmus (high level) or at/below the isthmus (low level). Closed reduction was initially preferred. Open reduction with percutaneous pinning was performed, when necessary. Flynn's criteria were used to evaluate elbow motion after treatment.

RESULTS: Mean follow-up time was 39 months (16–62 months). The mean age of the patients was 6.4±2 years (1.4–12 years). Thirty-nine of the patients were female, 73 were male; 32 fractures were in the dominant arm, 80 were in the non-dominant arm. Ninety of the fractures were classified as high level (proximal) and 22 as low level (distal). Patients with low-level fractures were significantly younger ($p<0.01$). Patients with low-level fractures also showed a significantly higher rate of conversion to open reduction compared to those with high-level fractures ($p<0.01$). Clinical outcomes evaluated with Flynn's criteria were statistically equivalent between the high and low fracture groups ($p>0.05$).

CONCLUSION: The Gartland classification provides important guidance for the treatment of supracondylar humerus fractures, but may have limitations. Our results suggest that revising the classification by incorporating fracture location may be more beneficial for pre-operative planning.

Keywords: Closed reduction; Gartland type III; open reduction; supracondylar humerus fractures.

INTRODUCTION

Supracondylar humerus fractures are the most common form of elbow fracture in children and adolescents.^[1] These frac-

tures occur more frequently in males and children aged 5–7 years.^[2] While Gartland type I fractures are treated more conservatively, Gartland type III fractures require reduction and percutaneous pinning.^[1,2] In cases, where closed reduc-

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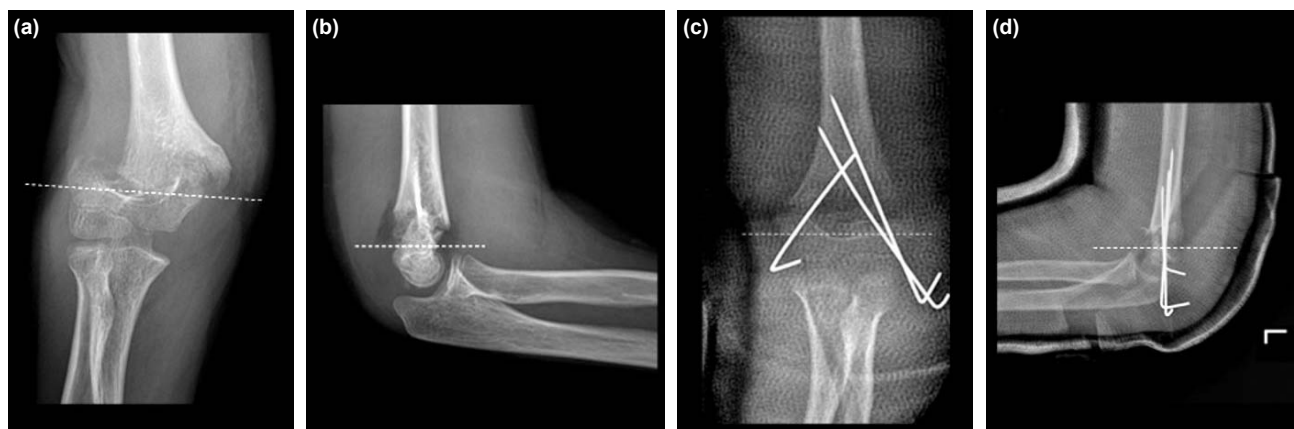


Figure 1. Pre-operative (a, b) and post-operative views (c, d) of high-level supracondylar humerus fracture

tion is unsuccessful, the procedure is converted to open reduction. Closed reductions provide accelerated fracture healing, faster superficial tissue healing, and better clinical outcomes.^[3,4] Various studies have suggested associations between conversion to open reduction and factors such as time to operation, patient weight, surgeon experience, and excessive edema around the fracture;^[5] however, no consensus has been reached regarding which patients are more likely to require conversion to open reduction.^[6-11]

Gartland type III fractures occur in the distal humerus and may be located above the isthmus (high level) (Fig. 1) or at/below the isthmus (low level) (Fig. 2).^[11] In the present study, we aimed to investigate the relationships between the fracture location and the rate of conversion to open reduction and clinical outcomes. Our hypothesis was that supracondylar humeral fractures located below humeral isthmus would be more susceptible to open reduction.

MATERIALS AND METHODS

A total of 112 patients who presented with Gartland type III supracondylar humerus fracture and underwent early surgery

(within 12 h of trauma) in our center between August 2011 and August 2017 were evaluated retrospectively. Approval of Institutional Review Board was obtained for this study. Patients with multiple injuries, open fractures, initial nerve and vascular injuries, compartment syndrome, bone disease, and any congenital or previous trauma-related deformities of the fractured arm were excluded from the study. Of those remaining, 112 patients, who signed the informed consent form, were included in the study. Patient data were obtained from the hospital inpatient unit records, emergency department records, and the radiologic picture archiving and communication system. The patients' age, sex, fracture side and location, post-operative loss of reduction, and complications were noted from these records. Surgical delay was defined as the time elapsed between the traumas and when the patient was taken into the operating room. Complications were evaluated as neurovascular injury, compartment syndrome, pin site infection, and late deformities (cubitus varus). The mean follow-up was 39 months (16–62 months).

Fracture level was determined by drawing a line through the distal humerus isthmus on coronal AP X-ray and an imag-

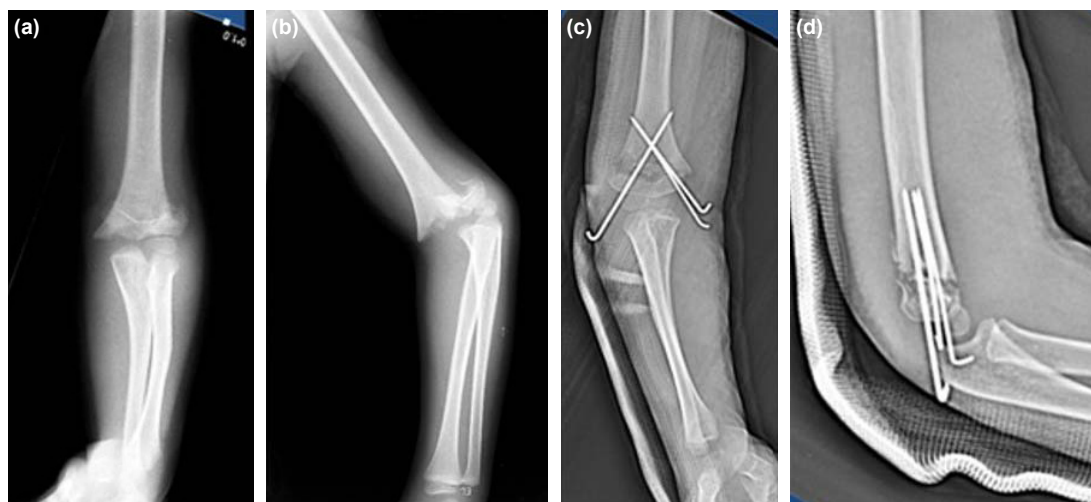


Figure 2. Pre-operative (a, b) and post-operative views (c, d) of low-level supracondylar humerus fracture

inary line through the lateral epicondyle, olecranon fossa, and medial epicondyle on anterior-posterior X-ray (Fig. 3). Fractures at and below the line were classified as low level (distal) (Fig. 2) and those above the line were classified as high level (proximal) (Fig. 1).^[12] Measurements were made preoperatively and postoperatively by two orthopedists working at the same center who had no knowledge of the study. Cases with inconsistent measurements and inappropriate radiographs were excluded from the study. After surgery, postoperative X-rays were compared to pre-operative X-rays. If any disagreement exists, these cases were also excluded from the study. In all other cases, there were no discrepancies between measurements.

Surgical Technique

All procedures in the study were performed by one of two senior orthopedic surgeons working in the clinic in an operating room equipped with fluoroscopy under general anesthesia with patients initially in supine position. Closed reduction was attempted first in all cases.^[12,13] In patients with successful closed reduction, 1.5 mm or 2.0 mm Kirschner wires (K-wires) were inserted laterally and medially for fixation. Stability of the fixation was checked under the fluoroscopy. If further stabilization was required, another K-wire was inserted laterally.

Open reduction was performed in the following situations:^[14,15]

- I. Inability to achieve closed reduction in an average period of 35 min and despite using four consecutive reduction

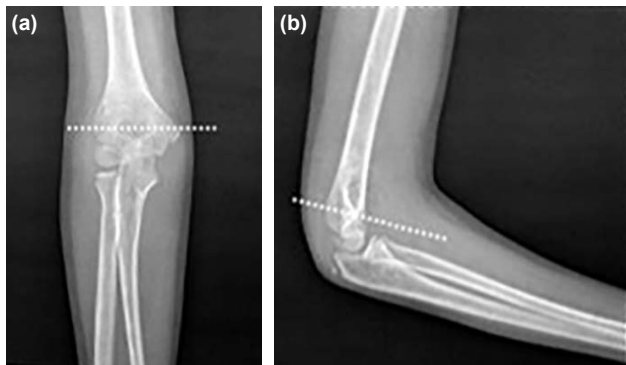


Figure 3. Demonstration of fracture level relative to humeral isthmus on biplanar radiograph.

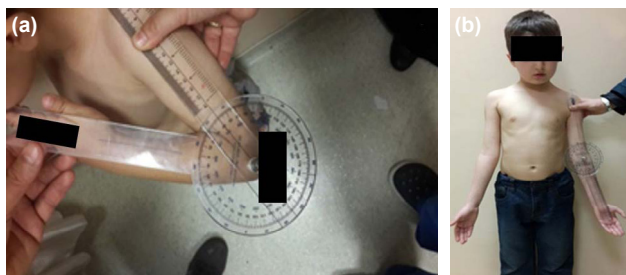


Figure 4. Measurement of range of motion (a) and carrying angle of the elbow using a goniometer (b).

- II. Presence of soft tissue between bone fragments and lack of crepitus during reduction maneuvers
- III. The distal fracture fragment appears rotated in intraoperative fluoroscopy and is irreducible

Posterior triceps split approach was used for open reduction as our surgeons had the most experience with this technique. Following posterior skin/subcutaneous tissue exposure through incisions extending 5 cm proximally and 2 cm distally from the olecranon tip (midline), the ulnar nerve was dissected and preserved. After achieving stable reduction, K-wires were inserted medially and laterally through the intact skin for fixation. Stability was checked by performing flexion and extension of the arm under fluoroscopy.

Despite the risk of ulnar nerve injury, a third K-wire was inserted due to enhanced biomechanical stability of cross wiring technique. The third K-wire was inserted laterally for fractures requiring additional stabilization. The skin and subcutaneous tissues were closed, the wires were cut and bent, and wound dressing was applied. The arm was splinted using a temporary 90–120° neutral position long-arm splint. The splint was removed after 24 h and a 90° hard cast was applied.

All patients had weekly follow-up examinations. After 4 weeks, the K-wires were removed under local anesthesia and active motion was initiated. Passive motion was initiated at 6 weeks and physiotherapy was recommended for patients with limited functional range of motion at post-operative 10 weeks. Patients were seen in the outpatient clinic for follow-up after treatment. Range of motion and carrying angle of both elbows were measured using a goniometer with patients in standing position (Fig. 4). The difference between the operated side and healthy side was accepted as the change in angle. Elbow movements were evaluated in terms of loss of functional range of motion and changes in cosmetic carrying angle according to Flynn's criteria (Table 1).

Statistical Analysis

NCSS 2007 and PASS 2008 Statistical Software (Utah, USA) were used for statistical analysis. Mean, standard deviation, median, frequency, ratio, minimum, and maximum values were used to present the study data in tables. The Kruskal–Wallis test was used for comparisons of variables with non-normal distributions between three and more groups, and the Mann–Whitney U test was used for comparisons of two groups. Significance was evaluated at $p < 0.01$ and $p < 0.05$ level.

RESULTS

The patients' mean age was 6.4 ± 2 years (1.4–12 years) and they were followed for a mean of 39 months (16–62 months). The patient group consisted of 39 females and 73 males; 32

Table 1. Flynn's criteria

Results	Loss of functional range of motion	Changes in cosmetic carrying angle
Excellent	0–5	0–5
Good	6–10	6–10
Moderate	11–15	11–15
Bad	>15	>15

Table 2. Reduction type according to fracture level

Fracture level	Loss of functional range of motion		Rate
	Closed reduction	Open reduction	
High level, n (%)	84 (93.3)	6 (6.7)	90 (84.7)
Low level, n (%)	17 (77.3)	5 (22.7)	22 (15.3)
Total, n (%)	101 (90.2)	11 (9.8)	112 (100)

of the fractures were in the dominant arm, 80 were in the non-dominant arm. Ninety of the fractures were classified as high level and 22 as low level. Only extension type 3 supracondylar humerus fractures were included in the study.

Mean age was 7.5 ± 3 years in the high-level fracture group and 5.2 ± 2 years in the low-level fracture group ($p < 0.01$). A total of 11 patients (9.8%) were converted to open reduction with internal fixation (Table 2). Conversion to open reduction was

necessary in 22.7% of cases with low-level fractures versus 6.7% of patients with high-level fractures ($p < 0.01$).

Clinical outcomes were assessed according to Flynn's criteria (loss of functional range of motion and changes in cosmetic carrying angle). Although the age group in the low-level fracture group was significantly lower than in the high-level fracture group, there were no statistically significant differences between the high- and low-level fracture groups ($p > 0.05$) (Table 3).

In terms of post-operative complications, four patients who underwent closed reduction with internal fixation developed ulnar nerve entrapment after surgery. These patients were followed without additional treatment or early pin removal. The issue completely resolved within 3 months in three patients and 5 months in the other. Two patients developed pin site infection, which was managed with oral antibiotherapy and wound dressing. No cubitus varus deformity developed in any patient. Loss of reduction occurred in five patients with closed reduction, two of whom underwent revision open reduction.

DISCUSSION

The optimal approach to Gartland type III supracondylar humerus fractures in pediatric patients is closed reduction and percutaneous pinning. In cases, where closed reduction cannot be achieved, the procedure is converted to open reduction. The previous studies reported a rate of 4–8% for open reduction consistent with our results.^[5,16–19] Even though pre-operative patient characteristics associated with higher probability of conversion to open reduction such as timing,

Table 3. Clinical outcomes according to Flynn's criteria

Outcomes	Fracture level		p-value
	Above isthmus (%)	Below isthmus (%)	
Type of reduction, n (%)			
Closed reduction	84 (93.3)	17 (77.3)	0.001 ^{***a}
Open reduction	6 (6.7)	5 (22.7)	
Loss of functional range of motion			
0–5 degrees	42	10	
6–10 degrees	29	6	
11–15 degrees	13	4	
>15 degrees	6	2	
Changes in cosmetic carrying angle			
0–5 degrees	47	10	0.874 ^b
6–10 degrees	26	8	
11–15 degrees	12	3	
>15 degrees	5	1	

^aFisher's Exact test. ^bFisher-Freeman-Halton test. ^{***} $P < 0.01$.

weight, and swelling in the fracture area have been suggested to play a role, the literature remains inconclusive regarding definitive predictors for open reduction. From this point of view, the ability to predict this phenomenon would assist in pre-operative planning and preparation.

There are numerous studies regarding conversion rates in early surgery versus delayed surgery.^[13,20-28] In a study by Iyengar et al.^[22] comparing open type III fractures surgically treated within the first 8 h and those treated more than 8 h after trauma, there was no statistically significant difference between the groups in conversion to open reduction or complication rates. Similarly, Leet et al.^[25] observed no statistically significant differences in terms of conversion to open reduction and complication rates in their comparison of type III fractures treated within or after the first 21 h of trauma. In contrast, a systematic review by Loizou et al.^[27] including 396 Gartland type III cases showed that late surgeries (more than 12 h post-trauma) had a significantly higher rate of conversion to open reduction compared to early surgeries (within 12 h post-trauma). Walmsley et al.^[28] also conducted a study comparing type III supracondylar humerus fractures operated within the first 12 h after trauma to those operated later. They reported no significant difference between the groups in perioperative complication rates, but the delayed surgery group had a higher rate of conversion to open reduction. It is clear from these studies that the impact of early or delayed surgery on rates of conversion to open reduction requires further elucidation.

All of the patients in our study underwent early surgery. By minimizing the effect of post-trauma surgery time, we attempted to identify other factors affecting conversion to open reduction. There are also studies indicating that extreme swelling of the elbow, vascular injury, and nerve injury also complicate closed reduction and increase the rate of conversion to open reduction.^[9,10,17,29] However, our study did not include cases with vascular or nerve injuries since these cases are more prone to open reduction and these could increase the rate of open reduction in study group regardless of fracture level.

The Gartland classification is used in treatment planning and evaluation of clinical outcomes for pediatric supracondylar humerus fractures. However, it may be inadequate for evaluating outcomes. From this point of view, the current study showed that the level of fracture is predictive to conversion to open reduction. Research has started to focus on the effect of fracture position relative to the condyle on post-operative outcomes. Kang et al.^[11] subclassified type III fracture levels as those above and those below the humeral isthmus. He evaluated these subgroups in terms of clinical outcome. This study showed that fractures below the isthmus were more common in patients aged 10 and older and were associated with poorer clinical outcomes compared to high-level fractures. This study found that poorer clinical outcomes in

low-level fractures. Separately, we aimed to investigate relationship between rate of open reduction and fracture level.

Unlike the aforementioned studies, we found that low-level supracondylar fractures were more common among children aged 7 years or younger. The age group in the low-level fracture group was significantly lower than in the high-level fracture group. Comparison of clinical outcomes evaluated with Flynn's criteria revealed no statistically significant differences between the high-level and low-level fracture groups. An important finding of our study was that the rate of conversion to open reduction was significantly higher for low-level fractures than for high-level fractures. One possible reason for this could be related to ossification process. Ossification of the elbow is known to increase with age.^[30] Our study indicates that traumas in early childhood (age <6 years) are more likely to result in low-level fractures. In our study, it is also possible that the presence of more ossified distal fragment in older age group could explain decreased rate of open reduction which is observed in younger age group with low-level fracture group. Ossified distal fragment in older children would have more wire holding potential than more cartilaginous distal fragment present in younger children. This likely raises possibility of more difficult closed reduction and increases the rate of conversion to open reduction. The mean age in high-level group was statistically higher than low-level fracture group; however, clinical outcomes were similar in both fracture groups which indicated that age factor did not influence clinical outcomes. This finding is contrarily to what has been reported in one study by Fletcher et al.^[31] where older children (age >8 years) more frequently underwent open reduction; however, it was not statistically significant.

Furthermore, forceful attempts at closed reduction are more likely to cause permanent damage to the cartilaginous tissues of this sensitive structure with low-level fractures in young patients. There is less amount of distal ossified fragment in low-level fracture group compared to high-level fracture group. This makes wire holding more difficult; therefore, we needed open reduction in low-level supracondylar fractures. Furthermore, it is technically more challenging to obtain K-wire purchase without separating small distal more cartilaginous fragment.

In addition, we believe that torn periosteum in low-level fractures (close to the joint) makes closed reduction difficult and also increases the rate of conversion to open reduction. Periosteum is an important structure for reduction in supracondylar humerus fractures. In supracondylar fractures, periosteum is detached from distal fragment. Small amount of distal fragment with torn periosteum in low-level supracondylar humerus fractures could make closed reduction challenging with risk of dynamic unstable fixation which is stated by Kang et al.^[11]

The small distal fracture fragment precludes insertion of the wires from the appropriate points, and the inserted wires

have reduced holding power, which makes it difficult to achieve closed reduction. These factors all demonstrate that fracture configuration is an important guide in planning surgical treatment and assessing clinical outcomes in supracondylar humerus fractures in children.

The retrospective study design, limited number of patients, and inclusion of procedures performed by two different surgeons are limitations of our study. Although both observed the criteria for converting to open reduction, there are subtle differences between surgeons. Therefore, prospective studies including larger patient groups are needed.

Conclusion

Our study indicates that low-level supracondylar fractures are more prone to conversion to open reduction. Our results also suggest that revising the Gartland classification by incorporating fracture location may be more beneficial for treatment planning.

Ethics Committee Approval: This study was approved by the Marmara University Faculty of Medicine Ethics Committee (Date: 04.07.2014, Decision No: 09.2014.0115).

Peer-review: Internally peer-reviewed.

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ORJİNAL ÇALIŞMA - ÖZ

Çocukluk çağı tip 3 suprakondiler humerus kırıklarında kırık yerleşiminin açık redüksiyon ve klinik sonuçlara olan etkisi

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AMAÇ: Suprakondiler humerus kırıkları, çocuk ve adölesan yaş grubunda en sık görülen dirsek kırığıdır. Tedavi planlaması, güncel olarak Gartland sınıflaması ile yapılmaktadır. Gartland tip 3 kırıklarda redüksiyon ve perkütan pinleme uygulanmaktadır. Kapalı redüksiyonun başarısız olduğu durumlarda, açık redüksiyon uygulanmaktadır. Ancak, hangi hastalarda açık redüksiyona ihtiyaç duyulacağı konusunda görüş birliği bulunmamaktadır. Çalışmanın amacı, kırık yerleşiminin açık redüksiyon oranı ve klinik sonuçlara olan etkisini araştırmaktır.

GEREÇ VE YÖNTEM: Ağustos 2011 ile Ağustos 2017 arasında Gartland tip 3 suprakondiler humerus kırığı nedeniyle başvuran 112 hasta geriye dönük değerlendirildi. Yaş, kırık yerleşimi, ameliyat sonrası redüksiyon kaybı ve komplikasyonlara ait veriler elde edildi. Hastalar, kırığın yerleşimine göre isthmus seviyesi üzeri (yüksek seviye) ve isthmus seviyesi/isthmus altı (düşük seviye) olmak üzere iki gruba ayrıldı. İlk olarak kapalı redüksiyon uygulandı. Kapalı redüksiyon ile redüksiyon sağlanamayan hastalarda açık redüksiyon ve perkütan pinleme uygulandı. Tedavi sonrası dirsek hareketlerinin değerlendirilmesinde Flynn's kriterleri kullanıldı.

BULGULAR: Ortalama takip süresi 39 aydı (16–62 ay). Ortalama yaş 6.4 ± 2 (1.4–12 years) yıldı. 39 hasta kız, 73 hasta erkek cinsiyetti. Otuz iki kırık dominant kolda, 80 kırık non-dominant kolda meydana geldi. 90 kırık yüksek seviye (isthmus üzeri), 22 kırık düşük seviye (isthmus seviyesi ve altı) olarak değerlendirildi. Düşük seviye kırıklı hasta grubunda ortalama yaş istatistiksel olarak daha azdı ($p < 0.01$). Düşük seviye kırıklı hasta grubunda açık redüksiyon oranı, yüksek seviye kırıklı hasta grubuna göre anlamlı olarak daha yüksekti ($p < 0.01$). Klinik sonuçlar Flynn's kriterleri ile değerlendirildiğinde her iki grup arasında anlamlı fark bulunmamaktaydı ($p > 0.05$).

TARTIŞMA: Suprakondiler humerus kırıklarının tedavi planlamasında Gartland sınıflaması önemli rehber olmaktadır, ancak kısıtlılıklar mevcuttur. Çalışmanın sonuçları, bu sınıflandırmaya kırık yerleşiminin dahil edilmesinin ameliyat öncesi planlamada faydalı olabileceğini göstermektedir.

Anahtar sözcükler: Açık redüksiyon; Gartland tip 3; kapalı redüksiyon; suprakondiler humerus kırıkları.

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