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Research Article

Predictive factors for the development of Gartland type IV supracondylar humerus fractures: a prospective clinical study

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ABSTRACT

Objective: This study aimed to identify the preoperative predictive factors for the development of Gartland type IV supracondylar humerus fracture based on the patient characteristic, fracture mechanism, and preoperative radiographic fracture characteristics.

Methods: This prospective study included the data of 120 patients with Gartland type III and IV supracondylar humerus fractures treated in a single center from 2020 to 2021. Patients' age, gender, height/weight percentile values, injury mechanisms, the proximity of fracture fragment to the skin (i.e., dimple sign), and time from trauma to surgical treatment were recorded. In the preoperative radiographs, the degree of extension or flexion deformity between fracture fragments in the sagittal plane, varus/valgus angulation between fracture fragments in the coronal plane, the amount of translation (medial or lateral) in the coronal plane, and the amount of osseous apposition between fracture fragments in the coronal plane were evaluated. With the authors' consensus, the patients were divided into 2 groups based on the presence of multidirectional instability during the intraoperative reduction: group 1 (Gartland type III; 99 patients) and group 2 (Gartland type IV; 21 patients). Fixation of the fractures was then completed.

Results: Significant differences were observed between groups in the valgus/varus angle and amount of osseous apposition ($P < .001$). Although no significant difference was found in terms of translation amount between the groups ($P = .088$), there was a significant correlation with medial translation in type IV fractures ($P < .001$). The correlation between the results and the groups was checked with Spearman's test. Medial translation ($r = 0.352$), varus or valgus angulation ($r = 0.616$), and osseous apposition ($r = 0.433$) exhibited a positive correlation. The probability of type IV fracture was modeled for the preoperative parameters using binary logistic regression. The regression analysis showed that the diagnosis of type IV supracondylar fractures could be predicted, if varus or valgus angulation was more than 25.5° (81% sensitivity, 85% specificity, odds ratio = 1.725; 95% CI = 1.170-2.541, $P = .001$, $r = 0.616$) and if the amount of osseous apposition was more than 9.5 mm (85% sensitivity, 81% specificity, odds ratio = 1.471; 95% CI = 0.714-3.029, $P = .001$, $r = 0.433$) in the preoperative radiographs. There was also a significant correlation between medial translation (varus angulation) ($P < .001$, $r = 0.352$), age ($P = .019$, $r = 0.255$), and patients with more than 90 height/weight percentile values ($P < .001$, $r = 0.508$) with the possibility to have Gartland type IV fractures.

Conclusion: This study has found some preoperative factors that may be relevant for type IV Gartland fractures. Height/weight values greater than the 90 percentile, varus or valgus angulation greater than 25.5°, bone apposition values greater than 9.5mm, medial translation values greater than 11mm, and older than eight years patients type IV fractures were more common in such patients. If surgeons can more accurately diagnose a Gartland type IV fracture preoperatively, the surgeon can more accurately inform the patient and plan better treatment.

Level of Evidence: Level II, Diagnostic Study

Introduction

Supracondylar humerus fractures (SCHFs) are common among elbow fractures in pediatric patients.[1] They are more common in boys aged 5-8 years and mostly occur in the nondominant arm.[2] They are classified as extension (98%) or flexion (2%) type according to the anteroposterior displacement direction in the lateral x-ray of the elbow.[3] The Gartland classification is commonly used to classify supracondylar humeral fractures.[4] Leitch added a new fracture type to the Gartland classification and named it type IV.[5] In type IV fractures, anterior and posterior periosteum tears completely, which causes instability of the fracture in both flexion and extension.[5] In type IV Gartland fractures, closed reduction and percutaneous pinning (CRPP) are often difficult due to multidirectional instability.[6] Therefore, open reduction and percutaneous pinning (ORPP) may often be required for the treatment of type IV fractures.[6]

Gartland type IV fractures are diagnosed in the operating room. Instability is only detected while performing manipulation for fracture reduction.[6] We hypothesized that Gartland type IV fractures can be preoperatively diagnosed, allowing the surgeon to better plan treatment and be better prepared for open reduction. The aim of this study was to show the predictive factors to diagnose Gartland type IV SCHFs preoperatively by evaluating patient data, the fracture mechanism, and the preoperative radiographic features of the fracture.

Materials and Methods

This work is a prospective study containing data from patients with SCHFs treated at our hospital between

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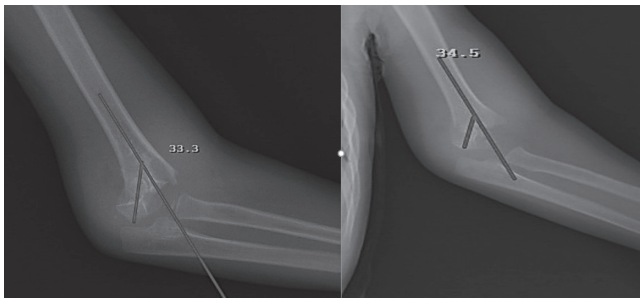

Figure 1. Angle between the line drawn parallel to the humeral shaft and the line parallel to the metaphysis of the distal fragment.

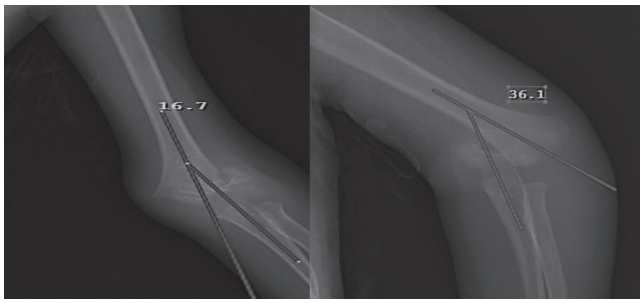

Figure 2. Angle between the line drawn parallel to the humeral shaft and the line parallel to the shaft of the ulna.

June 2020 and June 2021. Patients with Gartland type III and type IV SCHFs and complete records were included in the study. The study was started prospectively after approval by the Ethics Evaluation Committee of Dicle University (07.05.2020/135).

Patients who had skeletal dysplasia, a history of surgery around the elbow, an open fracture, direct open reduction due to arterial injury, a fracture reduction attempt in the emergency department, multiple traumas, and more than a 12-hour period between the trauma that caused the fracture and surgical treatment were excluded from the study. One hundred eighty-four SCHFs were treated at our hospital. One hundred fifty-six patients had Gartland type III or type IV fractures. Thirty-six patients were excluded from the study because they did not meet the inclusion criteria. The patients were divided into 2 groups: Gartland type III (group 1) and Gartland type IV (group 2).

The patients' age, gender, height/weight percentile values, injury mechanisms, proximity of fracture fragment to the skin (i.e., dimple sign), time between trauma causing the fracture, and the surgical treatment were noted. In the preoperative radiographs, the degree of extension or flexion angle between fracture fragments in the sagittal plane (Figure 1), varus/valgus angulation between fracture fragments in the coronal plane (Figure 2), the amount of translation (medial or lateral) in the coronal plane (Figure 3), and the amount of osseous apposition between fracture fragments in the coronal plane (i.e., cortical contact) (Figure 4) were evaluated.

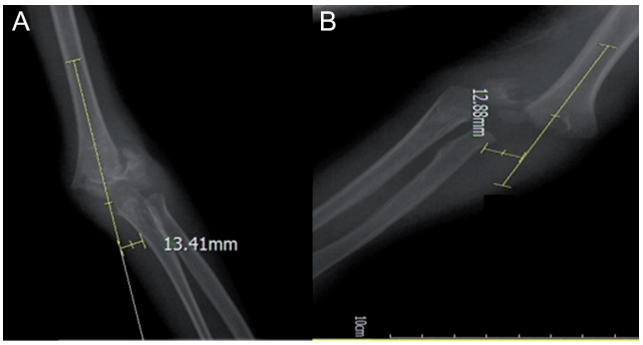

Figure 3. A-B. The distance from the line drawn parallel to the humeral shaft to the nearest place.

Three senior authors performed the entire surgical intervention. Any 2 of the 3 senior authors performed each surgery together to make an objective type IV decision. The accuracy and quality of the reduction were detected by intraoperative fluoroscopy.[6] If the reduction obtained in both flexion- and extension-type fractures is consistently impaired or if reduction cannot be achieved, the situation is named multidirectional instability.[6] With the consensus of the authors, the patients were divided into 2 groups, group 1 (Gartland type III) and group 2 (Gartland type IV), according to the presence of multidirectional instability during the intraoperative reduction, and the fixations were then completed. The 3 senior authors performing the surgeries measured preoperative radiographical parameters for each patient together at the same time and separately. The mean of the individual measurements was taken and compared with the measurement taken at the same time. Postoperatively, the duration of the operations and the surgical techniques (i.e., closed or open reduction) were evaluated according to fracture types.

Figure 4. Amount of osseous apposition between fracture fragments in the coronal plane.

HIGHLIGHTS

- Supracondylar humerus fractures (SCHFs) are common injuries in pediatric patients and Gartland type IV fractures are diagnosed in the operating room. This study aimed to show the predictive factors to diagnose Gartland type IV SCHFs preoperatively by evaluating patient characteristics, the fracture mechanism, and the preoperative radiographic features of the fracture.
- The results showed that patients with height/weight percentile values >90 were more likely to have type IV fractures. Medial translation was more common in type IV fractures. Older age, greater higher of coronal plane angulation and greater amount of bone apposition were olso associated with type IV fractures.
- The results from this study indicate that both age of the patient and the configuration seen on the x-ray imaging may guide the surgeon to a more accurate diagnosis of Gartland type IV fractures preoperatively, which may allow for a better treatment planning.

Written informed consent was obtained from the parents of all patients. All data were obtained without a personal identification document and were obtained in accordance with the Helsinki Declaration regulation.

Statistical Package for Social Sciences Version 23.0 statistical software was used to analyze the measured data (IBM SPSS Corp., Armonk, NY, USA). The numerical data obtained in the study are shown as mean ± SD (min–max), and categorical data are shown as frequency and percentage values. The Kolmogorov–Smirnov test was performed to assess the normality of the distribution of the numerical data. The Chi-square test and Student's *t* test were used to compare categorical data. For the preoperative parameters, the probability of type IV fracture was modeled using binary logistic regression. The correlation between the results and the groups was checked with the correlation test. Receiver operating characteristic (ROC) curves were used to compare the diagnostic values of radiographic parameters in estimating Gartland type IV fractures. The cutoff value of the parameters used in the ROC analyses was determined by taking the highest sensitivity and specificity values as references.

Results

One hundred eighty-four SCHFs were treated at our hospital. One-hundred fifty-six patients had Gartland type III and type IV fractures. Thirty-six patients were excluded from the study due to exclusion criteria, leaving 120 patients with Gartland type III and type IV SCHFs (group 1, 99 patients; group 2, 21 patients) aged between 3 and 12 years to be included in the study. Thirty-three of the patients in our study were female, and 88 were male. Sex ($P=.548$), mechanism of injury ($P=.351$), time between fracture occurrence and surgical treatment ($P=.052$), or dimple sign ($P=.078$) did not significantly differ between group 1 and group 2. Conversely, age and >90 height/weight percentile ($P < .001$) significantly differed between group 1 and group 2. Moreover, the varus or valgus angle ($P < .001$) and the amount of osseous apposition ($P < .001$) also significantly differed between groups.

Although the translation amount did not significantly differ between groups ($P=.088$), it significantly correlated with medial translation in type IV fractures ($P < .001$) (Table 1).

The correlation between the results and the groups was checked with Spearman's test. Medial translation ($r=-0.352$), varus or valgus angulation ($r=0.616$), and osseous apposition ($r=0.433$) were positively correlated (Table 2).

We looked for differences between the combined and individual measures of the authors. No difference was detected between the authors' combined and individual measurements (varus or valgus angulation ($r=0.998$), medial or lateral translation ($r=0.998$), amount of osseous apposition ($r=0.997$), and extension or flexion angulation ($r=0.999$) (Table 3).

For the preoperative parameters, the probability of type IV fracture was modeled using binary logistic regression. The diagnosis of type IV supracondylar fractures can be predicted based on varus or valgus angulation (odds ratio (OR) = 1.725; 95% CI = 1.170-2.541), bone apposition (OR = 1.471; 95% CI = 0.714-3.029), angle of flexion (OR = 0.876; 95% CI = 0.712-1.079), and translation amount (OR = 1.058; 95% CI = 0.796-1.406). No significant relationship with other preoperative parameters (such as age, sex, BMI, and fracture mechanism) was observed.

Table 1. Patient, treatment, and preoperative radiograph data (Chi-square test and Student's test were used)

	Gartland type III	Gartland type IV	*P*
Age	7.08 ± 2.8 years	8.28 ± 1.8 years	**.019**
Gender	27 female/72 male	6 female/15 male	.548
Extension or flexion angulation	19.55° ± 11.2°	22.8° ± 9.1°	.217
Extension or flexion type	98/1	19/2	.118
Varus or valgus angulation	16.3 ± 8.3°	38.2 ± 9.3°	**<.001**
Translation amount	11.09 ± 8.6 mm	14.57 ± 8.12 mm	.088
Medial or lateral translation	27/72	15/6	**<.001**
Amount of osseous apposition	6.9 ± 6.4 mm	10.28 ± 1.9 mm	**<.001**
50-75/75-90/>90 percentile values	45/48/6	0/9/12	**<.001**
Fracture mechanism: fall/sports injury	90/9	18/3	.351
Time between fracture occurrence and surgical treatment	7.66 ± 1.81 hours	8.85 ± 2.53 hours	.052
CRPP/ORPP	96/3	6/15	**<.001**

CRPP, close reduction and percutaneous pinning; ORPF, open reduction and percutaneous pinning.

Receiver operating characteristic curves were used to compare the diagnostic values of radiographic parameters in estimating Gartland type IV fractures. Specifically, a type IV supracondylar fracture was probable when the varus or valgus angulation exceeded 25.5°, with 81% sensitivity and 85% specificity; when bone apposition exceeded 9.5 mm, with 85% sensitivity and 81% specificity; when the flexion angle exceeded 15.5°, with 66% sensitivity and 56% specificity; and when the translation amount exceeded 11 mm, with 57% sensitivity and 61% specificity. We determined the probability of type IV fractures at high varus or valgus angles and high osseous apposition values. The area under the curve (AUC) of varus or valgus angulation was 0.927, the AUC of the amount of osseous apposition was 0.876, the AUC of extension or flexion angulation was 0.610, and the AUC of medial or lateral translation was 0.656 (Figure 5).

Discussion

To our knowledge, this work is the first prospective study to reveal predictive preoperative radiological factors to diagnose Gartland type IV SCHFs. Mitchell et al[6] published a retrospective study in 2019 in which 39 patients (20%) had type IV fractures. They analyzed patient data and preoperative x-ray parameters. In their study, they found a significant correlation between the parameters of flexion angulation, valgus angulation, lateral translation, and osseous apposition and the probability of predicting type IV fracture. Barik et al[7] reported a retrospective study in 2021 in which 17 of 33 patients had type IV fractures. In their study, they found that increased valgus angulation on preoperative x-ray was highly likely to be associated with type IV fractures. Conversely, they found no significant association with the amount of osseous apposition and lateral translation. In our study,

Table 2. Correlation Spearman test results

	Varus or valgus angulation	Medial or lateral translation	Amount of osseous apposition	Extension or flexion angulation	Age
r	0.616	−0.352	0.433	0.145	0.255
P	.000	.000	.000	.113	.022
N	120	120	120	120	120

r value: Correlation coefficient, p value: significant, N: total patients.

Table 3. Correlation Pearson test and intraclass correlation test results

		Measurement together	1. author	2. author	3. author	*r* (95% CI)	Significance
Varus or valgus angulation	Measurement together	1	0.988	0.988	0.997	0.998 (0.997-0.998)	.000
Medial or lateral translation	Measurement together	1	0.992	0.996	0.997	0.998 (0.998-0.999)	.000
Amount of osseous apposition	Measurement together	1	0.990	0.990	0.995	0.997 (0.996-0.998)	.000
Extension or flexion angulation	Measurement together	1	0.994	0.995	0.998	0.999 (0.998-0.999)	.000

the amount of flexion angle and translation, which are radiological parameters, did not significantly differ between groups, but we found a significant difference in the amount of varus or valgus angulation and bone apposition. In addition, a significant relationship was observed between medial translation and type IV fractures. Mitchell et al[6] found no significant relationship between age and body mass index and type IV fractures. In our study, we found a significant correlation between age (in patients older than 8 years of age) and increasing height/weight percentile values (especially in patients >90 percentile) and type IV fractures.

Leitch et al[5] demonstrated the multidirectional variant of unstable SCHFs in 2006. At the end of their study, which consisted of 9 patients, they defined the variant they identified as a modified Gartland type IV fracture. The incidence of this variant ranges from 7% to 10% of all surgically treated supracondylar fractures.[5] The type IV fracture variant is diagnosed intraoperatively, but it can vary according to surgical experience and is highly subjective. One of the etiological factors for type IV fractures is the formation of an iatrogenic capsular tear during surgical reduction. To avoid this tear, the senior authors who performed the surgery avoided excessively rigid traction and reduction maneuvers. The rate of type IV fractures in our study was 17.5%, which was higher than that in the literature. However, it is lower than that reported by Mitchell et al.[6]

Leitch et al[5] said that since extension-type Gartland type III supracondylar fractures are more stable than flexion-type Gartland type III supracondylar fractures, flexion-type supracondylar fractures should be considered type IV. Mitchell et al[6] found a very significant relationship between type IV fractures and Gartland type III flexion fractures. In our study, 1 patient in the Gartland type III fracture group and 2 patients in the type IV fracture group had flexion-type fractures. We did not detect a significant relationship. Type III flexion fractures were treated with CRPP, and 1 type IV flexion fracture was treated with CRPP and the other was treated with ORPP.

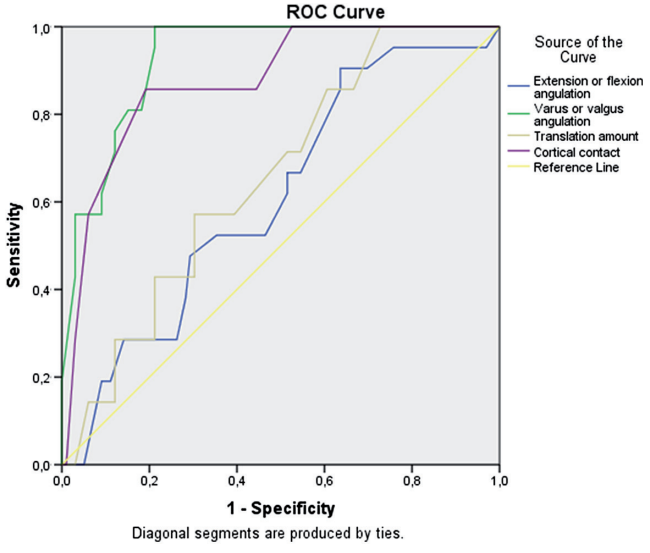

Figure 5. ROC curve.

The dimple sign is also called the pucker sign.[8] In SCHFs, it occurs when the proximal fragment pierces the brachialis muscle and adheres to the lower dermis layer of the skin.[8] This sign indicates that soft tissue interposition and closed reduction may be difficult. The dimple sign did not significantly differ between the type III and type IV groups in our study.

Sawaizumi et al[9] reported that soft tissue interposition to the fracture site is not always responsible for the failure of closed reduction in type IV fractures. If multidirectional instability is detected, forced closed reduction should be abandoned, and open reduction should be performed.[9] In the literature, longer operative times, longer hospital stays, and a higher frequency of open reduction have been reported in type IV fractures than in type III fractures.[10] In our study, we found longer surgery times and higher open reduction rates in type IV fractures than in type III fractures, but hospital stays were similar.

In our study, the time between fracture occurrence and surgical treatment did not significantly differ between type III and IV fractures ($P=.052$).

However, this period is longer in type IV fractures. Data on the time between fracture occurrence and surgical treatment were not available in the literature review. As this time passes, the resulting hematoma can become unstable. Additional work on this subject is needed. Open fractures or vascular injuries resulting from high energy have been studied in the literature. No significant relationship was found between the fracture mechanism and type IV fractures in fractures that met our study criteria ($P=.351$). The patients in our study group had fractures with low-energy results. Therefore, their data could not be compared with those in the literature.

Our study was subject to some limitations. Most importantly, an objective diagnostic test for type IV supracondylar humeral fractures is lacking. Therefore, the evaluation of this type of fracture is limited. Second, attention was given to x-rays in the appropriate position in all patients. Since all patients were children, x-rays may not be in the correct position in some patients, which may affect the angular computation result and even the statistical results of our study. In our study, "*r*" values and "OR" values were sometimes low, and scientific support is still needed. Additionally, some patients in the cohort may have had iatrogenic Gartland type IV fractures at the time of surgical reduction. Finally, the number of patients in the study was insufficient to make a firm judgment, and additional studies are needed. The strength of this study is that it is the first prospective study to identify predictive factors for type IV fractures.

In conclusion, we found some preoperative factors that may be relevant for type IV Gartland fractures. Height/weight values greater than the 90th percentile, varus or valgus angulation greater than 25.5°, bone apposition values greater than 9.5 mm, medial translation

values greater than 11 mm, and type IV fractures were more common in patients older than 8 years. If surgeons can more accurately diagnose a Gartland type IV fracture preoperatively, the surgeon can more accurately inform the patient and plan better treatment.

Ethics Committee Approval: Ethical committee approval was received from the Dicle University Medical Faculty Ethics Committee for noninterventional studies (07.05.2020/135).

Informed Consent: Written informed consent was obtained from the parents of all patients.

Author Contributions: Concept – Ş.Y., R.A., E.Ö.; Design – Ş.Y., R.A., H.A., M.S.A.; Supervision – Ş.Y.; Materials – Ş.Y., R.A., EÖ; Data Collection and/or Processing – Ş.Y., R.A., M.S.A.; Analysis and/or Interpretation – Ş.Y., R.A., E.Ö., H.A.; Literature Review – Ş.Y., R.A; Writing – Ş.Y., H.A., E.Ö.; Critical Review – H.A.

Declaration of Interests: The authors have no conflicts of interest to declare.

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