The goal of this study was to identify supracondylar fracture patterns that were predictive of adverse events and poor outcomes. The study consisted of a retrospective review of patients admitted for surgical treatment of a supracondylar humerus fracture between June 2008 and August 2010. Preoperative radiographs were assessed based on appearance (simple vs oblique vs comminuted), coronal plane displacement (angulated, posterior, posteromedial vs posterolateral), and rotation (rotation vs no rotation). Logistic regression models were used to examine the relationship between fracture pattern and clinical outcome parameters in 373 patients who were followed for 4 weeks or more postoperatively. Outcome parameters included postoperative complications (infection, delayed healing, pin migration, revision surgery), need for physical or occupational therapy, need for postoperative intravenous narcotics, and preoperative nerve injury. Rotation and coronal displacement patterns of the fracture segments were significantly associated with postoperative complications, postoperative need for physical or occupational therapy as a result of residual stiffness, and nerve injury ($P<.05$). Compared with posteriorly displaced fractures, posterolaterally displaced fractures were associated with significantly greater odds of complications ($P=.045$), need for physical or occupational therapy ($P<.001$), and nerve injury ($P<.001$). Additionally, fractures with rotation were associated with significantly greater odds of complications ($P<.001$), need for physical or occupational therapy ($P<.001$), and nerve injury ($P<.001$) compared with fractures without rotation. Rotation and coronal plane displacement were predictive of complications, need for physical or occupational therapy, and nerve injury, and thus should be considered as potential prognostic variables when evaluating the initial injury pattern.

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Supracondylar humerus fractures are the most common type of elbow fractures in children, accounting for 3% of all pediatric fractures, and they occur predominantly in children 5 to 7 years old.\(^1\)\(^2\) The Gartland classification is the most commonly used classification system used to describe supracondylar humerus fractures, differentiating type I (nondisplaced) from type II (intact posterior hinge) and type III (complete displacement) fractures.\(^3\) Wilkins\(^4\) and Leitch et al\(^5\) suggested additions to the classic scheme by adding subtypes IIA and IIB (rotational component) and type IV (unstable in both flexion and extension), respectively.\(^4\)\(^5\)

Any useful classification system should have strong interobserver and intraobserver reliability, provide basic treatment guidelines, and help to predict outcome. A recent analysis of the Wilkins modification of the Gartland classification system\(^4\)\(^6\) showed poor interobserver reliability for type I fractures, fair to moderate reliability for type II fractures, and good to very good reliability for type III fractures.\(^7\) The authors recommended treating pediatric supracondylar humerus fractures based on the degree of displacement rather than by applying the Gartland classification.\(^7\) Barton et al\(^8\) reported an intraobserver Kappa value of 0.84 and an interobserver Kappa value of 0.74. As a result, the authors cautioned against basing treatment decisions on the Gartland classification alone.\(^8\) The current study examined the relationship between coronal fracture displacement and rotational malalignment in supracondylar humerus fractures with adverse outcomes.

**Materials and Methods**

The study was a retrospective review of 517 skeletally immature patients who underwent operative treatment of a pediatric supracondylar humerus fracture at a single large tertiary pediatric hospital between June 2008 and August 2010. Approval was obtained from the institutional review board before study initiation. *International Classification of Diseases, 9th revision*, and Current Procedural Terminology codes were used to identify all patients. Exclusion criteria included missing, unreadable, or inadequate preoperative radiographs on presentation, open fractures, flexion-type supracondylar humerus fractures, and associated injuries requiring surgical intervention. The Figure provides a summary of subject enrollment.

A single author (M.A.F.) reviewed all preoperative radiographs to avoid bias. The following 3 fracture characteristics were analyzed: appearance (simple vs oblique vs comminuted), displacement (posterior, angulated, posteromedial vs posterolateral), and rotation (rotation vs no rotation). Based on lateral radiographs, rotation was defined as rotation of the lateral epicondyle toward (internal rotation) or away from (external rotation) the midline of the proximal humeral fracture segment. Simple fractures were defined as fractures with 2 main fragments, whereas oblique fractures had greater than 30° fracture angulation on anteroposterior, lateral, and oblique radiographs. Communion was defined as more than 3 fracture fragments. Fracture displacement was determined based on radiographs and was assigned to the following categories: posterior (fracture segment displaced posteriorly without coronal plane translation); angulated (fracture segment angulated posteriorly); posteromedial (fracture segment displaced posteriorly and translated medially); and posterolateral (fracture segment displaced posteriorly and translated laterally). All fracture pattern variables were identified as being potentially related to the clinical outcome variables of interest, based on previous literature or the expert clinical opinion of the fellowship-trained orthopedic faculty at the authors’ institution.

Surgical fixation of supracondylar humerus fractures was performed as follows. The elbow was prepared and draped in the usual orthopedic fashion. Closed reduction was accomplished with a combination of longitudinal traction, elbow flexion, and rotational correction, as indicated. The quality of reduction was confirmed with intraoperative fluoroscopy based on reduction in the anteroposterior, oblique, and lateral planes. Fracture fixation was achieved with percutaneous K-wires transversing the fracture in a spanning fashion. The number of K-wires (2 vs 3) and the use of lateral or medial K-wire entry or medial and lateral entry was based on fracture characteristics, fracture stability, and surgeon preference. Patients were placed into a bivalved long arm cast postoperatively and kept non-weight bearing. Postoperatively, patients returned for clinical follow-up within 7 to 10 days of surgery and again within 28 days of surgery for pin removal.

A total of 373 patients met the inclusion criteria and were followed for a minimum of 4 weeks postoperatively or until clinical and radiographic healing was achieved. The authors selected 28 days as the minimum duration of follow-up because immobilization is discontinued at approximately 28 days for most fractures. Radiographic union was defined as bony union in 3 or more of 4 cortices, and clinical union was defined as lack of tenderness to palpation and pain-free elbow range of motion, including flexion-extension and pronation-supination. K-wires were removed in the clinic on confirmation of union. No standardized physical or occupational therapy was prescribed. Patients

**Figure:** Summary of patient enrollment showing the reasons why patients were excluded as well as the final cohort used in the analysis.
were allowed to move the elbow as tolerated on K-wire removal and cast removal to regain elbow range of motion. Patients who did not obtain adequate range of motion on their own were prescribed dedicated physical or occupational therapy.

To assess the effect of the fracture pattern variables on clinical outcomes, the following primary outcome variables were obtained: operative time, nerve injury, need for physical or occupational therapy, and complications. Need for physical therapy was used as a surrogate variable for residual stiffness about the elbow joint that required additional intervention. A complication was defined as any of the following: delayed healing (radiographic evidence of a delay in healing that resulted in an extended casting period), a hardware-related complication, and need for reoperation. Additional covariates that were obtained included the number of people scrubbed during the primary surgical procedure, patient sex, patient age, concomitant fracture, mechanism of injury, type of surgical procedure (open vs closed reduction), need for an additional surgical procedure, and fracture type based on the Gartland classification system. For the mechanism of injury variable, a high-energy mechanism of injury was defined as a fall from greater than or equal to the patient’s height.

**Statistical Analysis**

The demographic and clinical characteristics of all patients were summarized with descriptive statistics. For binary outcome variables (complications, need for physical and/or occupational therapy, and nerve injury), logistic regression analyses were used to examine the relationship between the fracture pattern variables and the outcome variables of interest. Generalized estimating equations were used to account for the clustering effect of the treating surgeon. For each outcome variable, univariable analysis was used to identify potential confounding variables. Covariates significantly (P<.05) related to the outcome variables were controlled for in the final models that included the fracture pattern variables of interest.

Because Gartland type II and III fractures were included in the same cohort, a secondary subgroup analysis was used to test the association between the fracture pattern variables and the outcome variables of interest in patients with a Gartland type III fracture. Multivariable logistic regression analyses were used to test the association between fracture rotation, fracture displacement, and fracture appearance and complications, the need for physical or occupational therapy, and nerve injury. The goal of this analysis was to determine whether the fracture pattern variables identified as significantly related to the outcome variables of interest in the primary analysis were also related to the outcome variables of interest in a population of patients affected by fracture pattern type III, known to represent a more severe injury.

**RESULTS**

A total of 373 patients met the inclusion criteria. Mean age of patients in the study cohort was 5.7 years (range, 1.0-14.6 years). Table 1 lists additional demographic features. There was an even distribution of boys and girls. Three patients required open reduction and percutaneous pinning, and the remaining 370 underwent closed reduction and percutaneous pinning. Reasons for open reduction included suspected vascular injury (1) and failure to achieve satisfactory reduction (2). A total of 18 patients had additional bony injuries (radius or both-bone forearm fractures) that were treated conservatively with closed reduction and long arm casting after surgical treatment of supracondylar humerus fractures. Mean operative time for all patients was 28.3 minutes (range, 10-116 minutes).

Table 2 details the fracture patterns of the patients included in the study cohort. Of the patients, 167 had a Gartland type II su-
pracondylar humerus fracture and 206 had a Gartland type III fracture pattern. Most fractures were simple transverse fractures (287), followed by oblique fractures (58) and comminuted fractures (28). Most fractures were displaced straight posteriorly (173), followed by posterior angulation as the result of an intact posterior periosteal hinge (86). In addition, 60 patients had a posterolateral fracture displacement pattern and 54 had a posteromedial fracture displacement pattern. Rotational fracture displacement was observed in 76 patients.

After surgery, 52 patients (13.9%) needed physical or occupational therapy to address residual stiffness about the elbow joint. After controlling for age ($P<.001$), displacement ($P<.001$) and rotation ($P<.001$) of the fracture were significantly related to the need for physical or occupational therapy. The results of this analysis are provided in Table 3. The appearance (simple vs oblique vs comminuted) of the fracture was not significantly related to the need for therapy ($P=.619$).

A total of 50 preoperative nerve injuries were identified in 48 patients (12.9%). The injuries most frequently affected the median nerve (33, 8.85%), followed by the radial (13, 3.49%) and ulnar (4, 1.07%) nerves. After controlling for potential confounding variables (concomitant fracture, $P=.015$) in the multivariable analysis, the displacement ($P<.001$) and rotation ($P<.001$) of the fracture were significantly related to nerve injury (Table 4). The appearance (simple transverse, oblique vs comminuted) fracture pattern variable was not significantly related to nerve injury ($P=.936$).

A total of 23 (6.2%) patients had complications. Table 5 lists the incidence of delayed union, deep infection, pin migration, loss of reduction, and limited range of motion. In the univariable analysis, no potential covariates (additional fracture, age, sex, or mechanism of injury) were significantly related to complications. In addition, fracture appearance was not significantly related to complications ($P=.900$).

Displacement and rotation were significantly related to complications ($P=.037$ and $P<.001$, respectively). Table 6 lists the odds of postoperative complications based on fracture displacement.

**Subgroup Analysis of Type III Fractures**

A total of 206 patients with type III fractures were included in the secondary subgroup analysis. Fracture appearance was not significantly associated with the need for physical or occupational therapy ($P=.487$), nerve injury ($P=.579$), or complications ($P=.999$). Patients with laterally displaced fractures were significantly more likely to need physical or occupational therapy than those with medially displaced fractures (odds ratio, 3.2; 95% confidence interval, 1.2 to 8.6).
Fracture rotation was not significantly related to complications (P=.052).

### Discussion

The current study investigated the incidence of adverse events and the outcomes of pediatric supracondylar humerus fractures based on coronal fracture displacement and fracture rotation at the time of presentation. The study cohort included 373 consecutive patients. Posteriorimal, posterolateral, and rotational fracture displacement, but not comminution, was associated with a statistically significant increase in the incidence of postoperative complications and preoperative nerve injury. Patients with posterolateral and rotational displacement were also significantly more likely to need postoperative physical or occupational therapy as a result of joint stiffness. In the subgroup analysis of type III fractures, posterolateral and rotational displacement was also related to the need for physical or occupational therapy as well as nerve injury.

The overall complication rate (6.6%) reported was in line with previously published results. Ponce et al\(^9\) retrospectively reviewed the complication rate in a series of 104 consecutive patients who required closed reduction and percutaneous pinning and reported an overall complication rate of 7.7%. The prevalence of preoperative nerve injury after supracondylar humerus fractures was reported as 5% to 19%.\(^2\) Preoperative nerve injury in the current cohort was 12.8%. In a study of 622 patients, Bashyal et al\(^9\) described an overall complication rate of 4.2% and an incidence of pin migration of 1.8%, an incidence of deep infection of 0.2%, and an incidence of loss of reduction of 0.6%. The current data parallel these findings. In the current series, pin migration occurred in 0.3% of patients, deep infection occurred in 0.3%, and loss of reduction requiring revision surgery occurred in 0.3% (Table 5). Postoperative elbow stiffness requiring dedicated physical or occupational therapy has been reported as an exceedingly rare complication of supracondylar humerus fractures in the pediatric population.\(^2\) Henrikson\(^11\) reported an incidence of less than 5% in patients with postoperative loss of flexion or extension of greater than 5° compared with the uninjured contralateral side. In a series of 62 supracondylar humerus fractures, Persiani et al\(^12\) reported no disabling limitation of elbow function after operative repair. In sharp contrast, in the current study, 52 patients (13.9%) needed physical or occupational therapy because of residual stiffness about the elbow joint. Thus, the incidence of postoperative elbow stiffness after closed reduction and pinning of supracondylar humerus fractures may be much higher than previously anticipated.
or the authors’ institution may have used more aggressive physical or occupational therapy to address postoperative limitations of elbow range of motion.

Bahk et al. analyzed 4 coronal and 2 sagittal fracture subtypes in 203 consecutive patients. Significantly higher incidences of comminution and rotational malunion were reported in patients with more than 10° of coronal fracture obliquity, and significantly increased incidences of additional injuries and extension malunion were reported in patients with coronal fracture obliquity of greater than 20°. The authors concluded that sagittal and coronal fracture obliquity should influence surgical decision making and may affect outcomes. Although the authors did not analyze the current data set according to the coronal and sagittal fracture alignment parameters of Bahk et al., the current data suggested that coronal fracture orientation of greater than 30° or less than 30° is not significantly related to the outcome of supracondylar humerus fractures.

**Limitations**

The current study had several limitations. First, all data were collected retrospectively. Numerous surgeons were included in the study cohort, making the data potentially susceptible to bias. In addition, a standard follow-up period of 4 weeks was used, and important late postoperative complications, such as premature growth arrest, posttraumatic elbow deformity, or early osteoarthritic changes, may have occurred months to years after injury and may not have been detected. However, most patients (93.8%) in the cohort healed uneventfully, with no reported problems. Similarly, a substantial proportion (23%) of patients identified in the initial query were excluded because of lack of clinical follow-up. Clinical outcomes in patients who were excluded because of lack of follow-up were not considered in the current analysis.

Strengths of the current study included the large number of patients. To the authors’ knowledge, this is among the largest studies of outcomes after surgical fixation of supracondylar humerus fractures. Moreover, because this was a single-institution study, all patients were treated in a strictly standardized manner over the observed time. Follow-up was also uniformly standardized according to the protocol of the authors’ institution.

**CONCLUSION**

Based on the current data, posterolateral, posteromedial, and rotational fracture displacement, but not comminution, were associated with an increase in the incidence of nerve injury. Posterolateral and rotational fracture displacement was also significantly related to the need for postoperative physical or occupational therapy to address residual joint stiffness and postoperative complications. Rotational and coronal fracture deformity may more accurately reflect patient outcomes and may help the treating physician to better anticipate certain complications.

**REFERENCES**