Nonoperative Versus Operative Treatment of Type IIA Supracondylar Humerus Fractures: A Prospective Evaluation of 99 Patients

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Background: Although current clinical practice guidelines from the American Academy of Orthopaedic Surgeons suggest that Type II and III supracondylar humerus (SCH) fractures be treated by closed reduction and pin fixation, controversy remains as to whether type IIa fractures with no rotation or angular deformity require surgery. The purpose of our study was to prospectively compare radiographic and functional outcomes of type IIa SCH fractures treated with or without surgery.

Methods: Between 2017 and 2019, 105 patients between 2 and 12 years of age presenting with type IIa SCH fractures and without prior elbow trauma, neuromuscular or metabolic conditions, were prospectively enrolled. Ten orthopaedic surgeons managed the patients with 5 preferring surgical treatment and 5 preferring an initial attempt at nonoperative treatment. Patients in the nonoperative cohort were managed with a long-arm cast and close radiographic follow-up. Patients underwent a standardized protocol, including 3 to 4 weeks of casting, bilateral radiographic follow-up 6 months postinjury, and telephone follow-up at 6, 12, and 24 months.

Results: Ninety-nine patients met the inclusion criteria (45 nonoperative and 54 operatives). Of the nonoperative patients, 4 (9%) were converted to surgery up to their first clinical follow-up. No differences were identified between the cohorts with respect to demographic data, but patients undergoing surgery had on average 6 degrees more posterior angulation at the fracture site preoperatively ($P<0.05$). At the final clinical follow-up (mean = 6 mo), the nonoperative group had more radiographic extension (176.9 vs 174.4 degrees, $P=0.04$) as measured by the hourglass angle, but no other clinical or radiographic differences were appreciated. Complications were similar between the nonoperative and operative groups: refracture (4.4 vs 5.6%), avascular necrosis (2.2 vs 1.9%) and infection (0 vs 1.9%) ($P>0.05$). Patient-reported outcomes at a mean of 24 months showed no differences between groups.

Conclusion: Contrary to American Academy of Orthopaedic Surgeons guidelines, about 90% of patients with type IIa supracondylar fractures can be treated nonoperatively and will achieve good radiographic and functional outcomes with mild residual deformity improving over time. Patients treated nonoperatively must be monitored closely to assess for early loss of reduction and the need for surgical intervention.

Key Words: supracondylar fracture, type IIa

(*J Pediatr Orthop* 2023;43:e9–e16)

Supracondylar humerus (SCH) fractures remain a common injury managed by both pediatric orthopaedic specialists and general practitioners. The treatment of Gartland type I (nondisplaced) fractures with immobilization alone, and type III (completely displaced) fractures with closed or open reduction and percutaneous pinning is well established.[1] However, the management of type II (minimally displaced) fractures is more controversial.

Despite over 3 decades of evidence describing the successful treatment of most Gartland type II SCH fractures with closed reduction and immobilization,[2,3] there continues to be a tendency for these injuries to be treated

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The study was conducted at Rady Children's Hospital, San Diego, CA.
No external funding was received for this study. This study was supported by the Division of Orthopaedics, Rady Children's Hospital, San Diego. None of the authors received financial support for this study.
J.S.S. has the following disclosures: European Journal of Orthopaedic Surgery and Traumatology: Editorial or governing board. Orthopaediatrics: Paid consultant
A.T.P. has the following disclosures: Orthopaediatrics: Paid consultant. Pediatric Orthopaedic Society of North America: Board or committee member.
V.V.U. has the following disclosures: Daedalus Medical Solutions, Inc.: Employee. DePuy, A Johnson and Johnson Company: Paid consultant. EOS Imaging: Research support. Imagen: Stock or stock Options. Indius: Unpaid consultant. nView: Research support. Orthofix, Inc.: IP royalties; Paid consultant. OrthoPaediatrics: IP royalties; Paid consultant; Research support. Pacira: Paid consultant. Pediatric Orthopaedic Society of North America: Board or committee member. Scoliosis Research Society: Board or committee member. Spine: Editorial or governing board. Stryker: Paid consultant. Wolters Kluwer Health—Lippincott Williams and Wilkins: Publishing royalties, financial or material support. Zimmer: Research support.
The remaining authors declare no conflicts of interest.

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DOI: 10.1097/BPO.0000000000002282

operatively. Although pin site infection is rare, with a recently reported incidence of 0.81%, this is a complication that is unique to operative management.[4] Despite only "moderate" support, with low-level evidence, the American Academy of Orthopaedic Surgeons published Appropriate Use Criteria (AUC) guidelines in 2015 supporting universal surgical management of type II fractures.[5]

Not all type II SCH fractures behave similarly, and the Wilkins modification of the Gartland classification describes type IIa fractures as those with extension deformity alone, in contrast to IIb fractures, which also have rotatory or coronal malalignment.[6] Many retrospective studies have compared operative and nonoperative management of all type II fractures, and there is evidence to suggest that rotational deformity and varus or valgus alignment increase the likelihood of failure of nonoperative management,[7–9] supporting the more routine surgical treatment of type IIb injuries. However, there is a paucity of data to guide decision-making for type IIa SCH fractures. This study sought to prospectively evaluate type IIa injuries specifically. We hypothesized that the majority of these fractures can be safely and successfully treated nonoperatively.

METHODS

Between 2017 and 2019, 105 consecutive patients between the ages of 2 and 12 years who presented with acute type IIa SCH fractures were prospectively enrolled into an IRB-approved study at a tertiary care pediatric specialty hospital. Patients with prior elbow trauma and neuromuscular, or metabolic conditions were excluded. Ten fellowship-trained orthopaedic surgeons managed the patients, with 5 committing to surgical treatment and 5 committing to an initial attempt at nonoperative treatment. Patient treatment was therefore randomized by presentation based on the surgeon on-call. Patients in the nonoperative cohort were managed with a closed reduction (with or without sedation) and a long-arm cast with a mold to prevent extension deformity was placed. Reduction was performed by either an NP, PA, or MD from the Orthopaedic Surgery department. Casts were bivalved and positioned with the elbow in <90 degrees of flexion with the forearm in neutral. Patients were followed closely according to standard institutional protocol with radiographs at 1 week postreduction to confirm stability, and those with unacceptable fracture alignment were subsequently converted to surgery. Unacceptable alignment was defined as this can be a lowercase a lack of intersection between the anterior humeral line and the capitellum, or any malalignment in the coronal plane. Patients in the operative cohort were treated with closed reduction and percutaneous pinning with 2 lateral pins, followed by long-arm casting. All patients underwent a standardized protocol, including 3 to 4 weeks of casting, bilateral radiographic follow-up at 6 months postinjury, and telephone follow-up at 6, 12, and 24 months to obtain patient-reported outcomes. Patients that were converted from nonoperative to operative treatment were maintained in the nonoperative cohort for an intention-to-treat analysis.

Radiographic measurements included the distal humeral hourglass angle (HGA), which is measured by drawing 2 lines bisecting the superior and inferior aspects of the distal humeral hourglass on the lateral view and subtending the angle posteriorly between them. The normal value is 178 degrees and this measurement has been shown to have excellent interobserver reliability.[10] Other radiographic measurements included the Baumann angle and displacement of the center of the capitellum from the anterior humeral line. Displacement of the capitellum from the anterior humeral line measurements was performed from the anterior humeral line to the center of the capitellar ossification center. Because the center of the capitellum typically sits anterior to the anterior humeral line almost all of the contralateral comparison elbows have a positive value in the range of 2 mm to 4 mm. All radiographic measurements were performed by a senior fellowship-trained pediatric orthopaedic surgeon (AP). Clinical outcomes included carrying angle, elbow flexion, elbow extension, and total arc of motion and were measured with goniometers. Clinical data were obtained by experienced advanced practice providers on the study team (CP and PS). Patient-reported outcomes of fracture healing upper extremity were used to assess functional measures. Questionnaires were provided in both English and Spanish depending on the families' preferences.

Descriptive data were tabulated with continuous variables reported as average ± SD and categorical variables as frequency and/or percentages. The operative groups were compared utilizing analysis of variance for continuous variables, or Mann Whitney U test if normality or homogeneity of variance assumptions were violated. Groups were compared using the χ^2 test for categorical variables. No priori power analysis was performed. Given the limitation in volume at a single tertiary care referral center, we chose to enroll for 1 year. We estimated that the convenience sample would be ~100 patients during that period of enrollment. Alpha was set at <0.05 to declare significance. Statistical Package for the Social Sciences (SPSS) v. 27 was used for all analyses (IBM Corp. Released 2020. IBM SPSS Statistics for Windows, Version 27.0, Armonk, NY: IBM Corp.).

RESULTS

Six patients of the initial 105 enrolled were excluded from the final analysis due to loss to follow-up, leaving 99 patients who met the inclusion criteria (45 nonoperative and 54 operative). No differences were identified between the cohorts with respect to demographic data (Table 1). The average age at the time of injury was 5.4 years (± 2.5 y). There were radiographic differences between the 2 groups, with the operative group demonstrating 1.7 mm more displacement of the capitellum from the anterior humeral line ($P=0.006$) (Table 1). Patients who underwent surgery were also 6 degrees more extended at presentation than those treated without surgery ($P=0.002$). Of the nonoperative patients, 4 (8.9%) were converted to surgery

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TABLE 1. Baseline Parameters (Mean ± SD, %)

	Nonoperative	Operative	*P*
Age at injury (y)	5.4 ± 3	5.4 ± 2	0.922
Sex (M/F)	41%/59%	54%/46%	0.221
Side injured (Right/Left)	38.5%/61.5%	43.5%/56.5%	0.640
Baumann angle (degree)	74.9 ± 6.5	73.1 ± 6.3	0.202
Displacement from anterior humeral line (mm)*	−1.7 ± 2.4	−3.5 ± 3.5	**0.006**
HGA (degree)	164.4 ± 7.6	158.3 ± 10.4	**0.002**

Bold values indicate statistical significance.
*Negative values denote the center of the capitellum was posterior to the anterior humeral line.
Baumann angle normative value is 64 to 81 degrees.
Hourglass angle normative value is 177.8 degrees.
HGA indicates Hourglass angle.

at an average of 10.5 days (range 8 to 13 d) postreduction after radiographs demonstrated unacceptable reduction.

Patients were followed clinically for an average of 193 days (6.4 mo) (202 d in the nonoperative group and 187 d in the operative group). At the final clinical follow-up, carrying angle, flexion, and extension were similar between the cohorts. The final arc of motion was 138 degrees in the nonoperative cohort and 141 degrees in the operative cohort ($P = 0.37$), compared with the contralateral, uninjured arc of motion of 148 degrees in the nonoperative cohort and 145 degrees in the operative group ($P = 0.52$). Four patients in each cohort (12.5% in the nonoperative group and 9.8% in the operative group) presented with final flexion <120 degrees ($P = 0.72$). Three patients in the nonoperative group (9.1%) and 2 patients in the operative group (5.1%) had final extension > 5 degrees ($P = 0.655$).

Final radiographic follow-up was performed at an average of 190 days (6.3 mo) (207 d in the nonoperative group and 175 d in the operative group). The nonoperative group was noted to have on average 2.6 degrees more extension as measured by the HGA ($P = 0.04$), but no other radiographic differences were appreciated. Some residual deformity was noted in 62.2% of patients treated nonoperatively, compared with 44.4% of surgical patients ($P = 0.043$). Remodeling was noted on 6-month radiographic follow-up in 4.4% of the nonoperative cohort and 5.6% of the operative cohort. Final radiographic follow-up data can be found in Table 2.

Complications were similar between nonoperative and operative cohorts in aggregate (4.4 vs 7.4%) as well as individually for refracture (4.4 vs 5.6%) and this can be changed to "avascular necrosis (AVN)" (2.2 vs 1.9%). All patients with avascular necrosis also had a refracture. Most refractures were extension-type SCH fractures, with the exception of 1 patient who presented with a lateral condyle fracture. Refractures occurred at a mean of 12.4 months (range: 5.0 to 19.6 mo). There was 1 infection in the operative group (1.9%). This patient was found to have a deep pin site infection at 2 weeks postoperative and was taken back to the operating room to have irrigation and debridement of the elbow. Intraoperative cultures grew Methicillin-sensitive Staphylococcus, and she was treated with a 6-week course of Cephalexin and went on to heal without any issues. There were no anesthesia-related complications in the operative group.

Six patients were lost to follow-up before 12 weeks. All patients were doing well and had healed their fractures, with the exception of 1 patient who demonstrated radiographic deformity at their last recorded visit at 35 days posttreatment. This patient was treated with reduction and casting in the emergency department, however, has not followed up for further elbow pain or deformity.

Patient-reported outcomes using the Patient-reported outcomes of fracture healing questionnaire at 24 months showed no differences between groups, with > 89% of families being satisfied with the appearance of the arm, 98% of patients experiencing no pain, and 98% experiencing no limitation ($P > 0.05$) (Table 3).

DISCUSSION

Historical complications associated with nonoperative management of SCH fractures, such as Volkmann ischemic contracture and angular deformity, incited a strong push for universal operative management of these fractures in the late 20th century.[11–13] This resulted in a dramatic increase in operative management throughout the world.[14,15] However,

TABLE 2. Final Radiographic Follow-up Data

	Nonoperative	Operative	*P*
Time to final x-ray (d)			
Mean ± SD	207.0 ± 181.9	175.1 ± 178.9	0.398
Range	21-611	9-761	
Baumann angle—ipsilateral			
Mean ± SD	72.1 ± 6.7	71 ± 5	0.381
Range	57-96.7	60-84	
Baumann angle—contralateral			
Mean ± SD	72.0 ± 6.0	72.7 ± 4.1	0.699
Range	63.5-86.5	62.8-78.9	
Displacement from anterior humeral line			
Mean ± SD	1.0 ± 3.0	2.4 ± 2.5	0.018
Posterior humeral line—ipsilateral			
Range	−12-6.6	−2.1-7.6	
Displacement from anterior humeral line			
Mean ± SD	4.4 ± 1.6	4.9 ± 2.3	0.554
Posterior humeral line—contralateral			
Range	2.1-6.8	0-9.6	
HGA—ipsilateral			
Mean ± SD	174.4 ± 6.5	176.9 ± 4.3	0.04
Range	157-185	164-184	
HGA—contralateral			
Mean ± SD	180.2 ± 2.1	180.7 ± 2.3	0.509
Range	175-184	177-185	

HGA indicates Hourglass angle.

TABLE 3. Selected PROOF Functional Outcomes at Final Follow-up

	Nonoperative, n (%)		Operative, n (%)		*P*
	Yes	No	Yes	No	
Does your injured arm look different from the uninjured arm?	6 (13.3)	39 (86.7)	4 (7.4)	50 (92.6)	0.505
Are you bothered by the way your injured arm looks?	2 (4.4)	43 (95.6)	2 (3.7)	50 (92.6)	0.98
Do you have any discomfort/pain with your injured arm compared with the other side?	1 (2.2)	44 (97.8)	1 (1.9)	53 (98.1)	0.99
Do you have any limitations with your injured arm compared with the other side?	2 (4.4)	43 (95.6)	0	54 (100)	0.204

these historical complications occurred at a time when skeletal traction, skin traction, and hyperflexion casting were all widely used.[16] As our understanding of these fractures and their treatment has evolved, splint or cast immobilization at <90 degrees and closed or open reduction and percutaneous pinning are now the mainstays of treatment. These changes in practice necessitate a modern assessment of the risks and benefits of treatment options. Therefore, the commonly cited low complication rates (2.1% to 4%) with modern operative management of type II fractures[1,17–19] should be compared with modern complication rates associated with nonoperative treatment for surgeons to make informed decisions regarding preferred treatment modalities. The complication rate associated with nonoperative treatment in our nonoperative cohort was 4.4%, which was not significantly different than the complication rate in the operative group (7.4%). However, although unusual, deep pin site infections (1.9% in our study) are not benign complications, particularly if they require a return to the operating suite.

Our relatively high rate of refracture was a surprising finding. All refractures were extension-type SCH fractures except for 1 lateral condyle fracture. Previous literature describes refractures occurring at an average of 26 months posttreatment.[20] Specifically, the lateral condyle refracture after SCH fracture described by Davids et al[21] was theorized to be related to late varus deformity, however, this was not noted in our population. Although our refracture rate was higher than expected, it was not high enough to draw additional conclusions. avascular necrosis occurred in 1 patient in each group, also a surprising finding. We suspect that this occurs more commonly than previously noted, as most practices do not follow radiographs of SCH fractures past 1 to 2 months postinjury.

Given that only 8.8% of patients initially treated nonoperatively required surgical intervention, if all type IIa SCH fractures in our study were treated operatively, 91.2% would have undergone an unnecessary surgical intervention. This estimation is slightly higher than, but consistent with, previous studies' conclusion that universal pinning of type II fractures results in 72% to 77% unnecessary procedures.[2,3,22] The cost and resources required for these avoidable operations are not negligible. In 2020, the average cost of percutaneous pinning of SCH fractures was $2,955.80 to $5,254.40, depending on whether the patient was treated at a community hospital or a tertiary hospital, with OR costs responsible for 64% to 74% of these total costs.[23] Savings with nonsurgical management are compounded if closed reduction and immobilization can be performed in the emergency department[24] rather than in the clinic, although conscious sedation costs can be significant.[25] Although no specific data regarding the cost of emergency department management specifically for SCH fractures is available, we do know that the costs in the emergency department vary greatly by region and by type of sedation performed,[26,27] and PHIS data demonstrates that surgical treatment of pediatric distal radius fractures results in hospital costs over 500% of nonsurgical treatment.[26] Future studies directly comparing the costs of operative fixation versus sedated reduction and casting in SCH fractures would inform this discussion dramatically.

Several retrospective studies have suggested that type II fractures with less extension and minimal swelling have higher chances of being successfully treated nonoperatively than those with more extension or more swelling.[7–9] One study reported that in patients with > 10 degrees of extension on initial radiographs, 48% will lose > 5 degrees of reduction after attempted closed reduction and immobilization under conscious sedation.[28] Larger, more recent studies confirmed that initial radiographic features differ significantly between those type II fractures that succeed with nonoperative treatment versus those that do not. Spencer and colleagues performed an extensive retrospective review of type II SCH fractures and compared 3 groups: those treated successfully nonoperatively, those treated initially with surgery, and those that required conversion to surgical treatment after initial nonoperative management. They determined that rotational deformity, varus or valgus malalignment, and shaft condylar angle (SCA) of <30 degrees were strongly related to surgical management.[9] These findings support the treatment of IIb fractures operatively and inspired the current study's focus on type IIa fractures specifically for a more in-depth study without the variables already known to contribute to the failure of conservative management.

Varying rates of success of nonoperative treatment have been reported. Two studies with relatively small sample sizes reported 100% success rates in type IIa fractures with casting, splinting, or flexion/pronation taping.[29,30] In studies that include both IIa and IIb fractures, there is an expected decrease in success rates. In the Thai experience, 84% of patients with type IIb SCH fractures failed closed treatment, along with 50% of those with type IIa SCH fractures.[31] Most studies report a much higher success rate. Parikh et al[3] noted a 72% success rate with closed reduction and casting under conscious sedation with both IIa and IIb fractures. Both American and Italian authors have published an 80% to 86% success rate with initial closed reduction and immobilization in all type IIs.[8,24] Ojeaga et al[10] reported a 76% success rate with nonoperative management of all type II fractures, with 1 important predictor of success being procedural sedation during reduction. As noted above, 91.2% of patients with type IIa SCH fractures in our study were successfully treated nonoperatively. Importantly, our protocol of casting in a position of <90 degrees of flexion indicates that after reduction, acceptable alignment can be maintained without hyperflexion, eliminating the historical concern for compartment syndrome in swollen, hyperflexed elbows. These findings, along with evidence that actual practice at level 1 pediatric trauma centers varies from the AUC,[22,32] support the modification of the AUC to support the treatment of type IIa fractures without surgical intervention.

The 4 patients in the current study that crossed over from the nonsurgical to surgical groups due to loss of reduction underwent fixation at an average of 10.5 days postinjury (Fig. 1). We, therefore, recommend radiographic monitoring at 7 to 14 days postreduction to confirm that there is no need for operative intervention. Previous studies have demonstrated that delayed fixation is not a risk factor for any complications, including increased length of surgery, need for open reduction, or compromise in final range of motion or carrying angle.[17,33] Although we do not recommend treatment of type II fractures with immobilization only (ie, no reduction maneuver), it is interesting to note that Moraleda et al[34] reported on the natural history of 46 patients treated in this manner, and found that the majority had good functional outcomes, with mild cubitus varus and extension deformities but maintained arc of motion.

Residual deformity and loss of motion are well-recognized complications associated with all SCH fractures, regardless of management. Long-term follow-up of 111 patients at an average of 12 years posttreatment for SCH fractures of all types indicates that up to a quarter of patients have differences in the range of motion between their injured and noninjured elbow of over 10 degrees, with loss of the flexion being almost universal. A decrease in carrying angle is also found in more than a third of these patients. Despite this, the patient-reported outcomes were excellent.[35] In our study, there was no statistically significant difference in the final carrying angle or arc of motion. There was a small subset of patients in each group who demonstrated <120 degrees of flexion or > 5 degrees of extension at final follow-up (Fig. 2). Functional arc of motion in children and adolescents has been described as 30 degrees of extension to 130 degrees of flexion, although contemporary activities

FIGURE 1. Case example of a patient who was initially treated nonoperatively and was converted to surgical fixation after loss of reduction.

such as holding a cell phone often require more flexion (up to 148 degrees).[36]

Previous studies have reported a 14% incidence of residual sagittal plane deformity after nonoperative management of type II SCH fractures at short-term follow-up, with equivalent functional outcomes in patients with and without this deformity.[37] Radiographic parameters of any kind may not correlate with patient-reported functional outcomes at all.[38] Remodeling of coronal plane deformities after fracturing at medium-term follow-up in the distal humerus has been shown to be poor,[39] however data is lacking to support or refute remodeling in the sagittal plane. In our study, some residual deformity was noted at 6-month radiographic follow-up in 62.2% of patients treated nonoperatively, compared with only 44.4% of surgical patients ($P = 0.043$). This was defined as any deviation > 5 degrees from the contralateral side in either the Baumann angle or the HGA. Interestingly, remodeling was noted in 4.4% of the nonoperative cohort and 5.6% of the operative cohort (Fig. 3). Future long-term studies will be needed to determine the expected rate of remodeling in the sagittal plane in distal humerus fractures.

Of note, concern for neurovascular compromise is commonly cited as a reason for surgical management of SCH fractures, however, vascular injury is essentially nonexistent in type II injuries.[18,22] Therefore, a patient presenting with vascular compromise and radiographs demonstrating a minimally displaced fracture should be suspected to have an occult type III, IV, or flexion-type injury and should be treated more aggressively.

Finally, we strongly encourage shared decision-making with both surgeon and family carefully considering the risks and benefits of operative and nonoperative treatment. Risk tolerance, cost, and social impact of the need for close follow-up vary from patient to patient. The pediatric orthopaedic surgeon plays an important role in providing both information and guidance to families.

The limitations of this study are multiple. There is no true randomization, as patients were randomized by predetermined surgeon preference. Patients treated operatively did have more extension and more displacement at presentation than those that were treated nonoperatively. We attempted to mitigate this difference with the intention-to-treat analysis, however, these baseline differences should be taken into consideration when interpreting the final data. Nonoperative closed reductions were performed utilizing a combination of techniques, unfortunately, we did not collect this information prospectively, which limited our ability to evaluate differences in closed treatment methods such as adverse reactions to the sedation methods utilized compared with those without sedation. However, no adverse reactions were noted in the medical records. Clinical measurements were performed by multiple providers, introducing the possibility of measurement error and variance in technique. Similarly, all radiographic measurements were performed by a single nonblinded senior author, introducing the possibility of bias. Given the limited sample size, this study may be underpowered to demonstrate some differences between the groups, particularly in complications. Finally, a 6-month radiographic follow-up is likely not long enough to determine the true incidence of residual deformity after operative or nonoperative treatment of these fractures or the degree of remodeling to be expected. Future studies should endeavor to provide long-term clinical and radiographic follow-up to satisfactorily address these concerns.

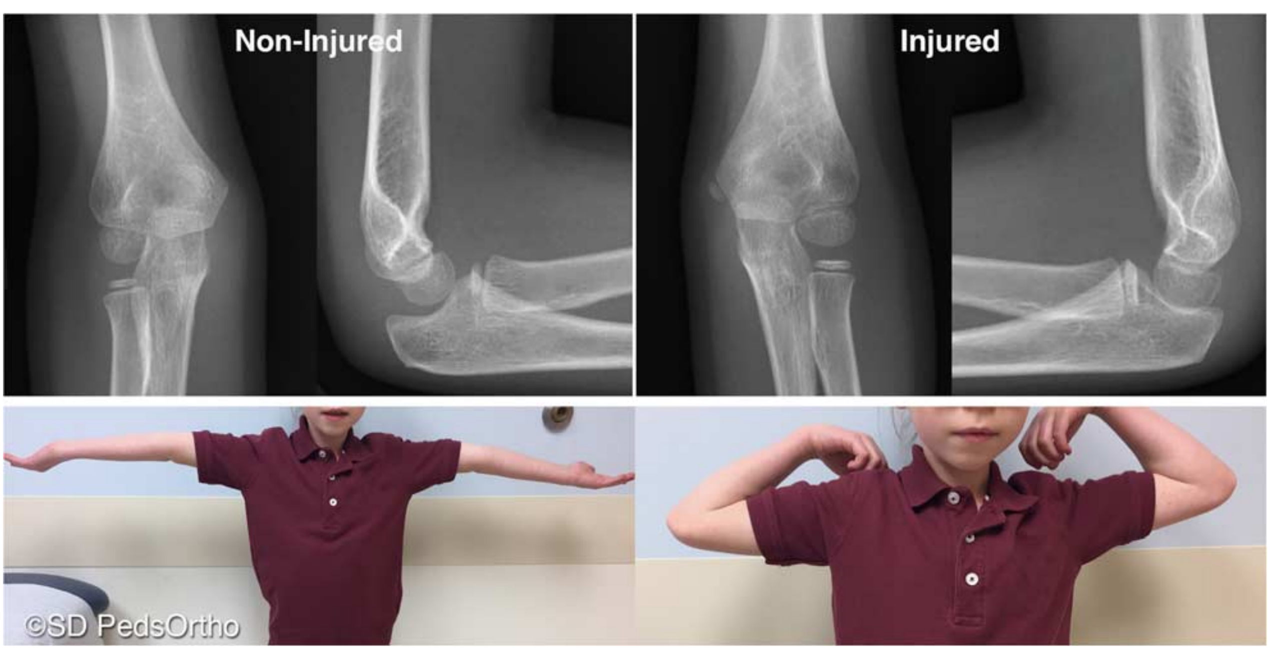

FIGURE 2. Case example of a nonoperative patient with mild hyperextension and loss of flexion compared with the contralateral side. Radiographs and clinical photos taken at 6-month postinjury.

FIGURE 3. Case example of a nonoperative patient with a mild residual deformity at the time of cast discontinuation that predominantly remodeled 12-month postinjury.

CONCLUSIONS

Patients with type IIa SCH fractures treated nonoperatively can achieve good radiographic and functional outcomes, but need to be observed closely to ensure no early loss of reduction. We support the modification of the American Academy of Orthopaedic Surgeons AUC to include nonoperative management of type IIa SCH fractures nonoperatively as an appropriate treatment option.

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