Journal of the Pediatric Orthopaedic Society of North America 8 (2024) 100079

Contents lists available at ScienceDirect

Journal of the Pediatric Orthopaedic Society of North America

journal homepage: www.jposna.com

Original Research

Factors Associated with Failed Closed Reduction in Flexion and Gartland Type III Pediatric Supracondylar Humerus Fractures

Pablo Coello, BSA[1,*]; Nathaniel Grey Loyd, BS[1]; David A. Hsiou, BS[1]; Rachel S. Silverstein, MD, MBS[2]; Scott B. Rosenfeld, MD[1,3]

[1] Department of Orthopaedic Surgery, Baylor College of Medicine, Houston, TX, USA
[2] Department of Orthopaedics and Sports Medicine, Nemours Children's Healthcare, Delaware, NJ, USA
[3] Department of Orthopaedics, Texas Children's Hospital, Houston, TX, USA

ARTICLE INFO

Keywords:
Supracondylar humerus fracture
Pediatric elbow fractures
Open reduction
Percutaneous pinning
Failed closed reduction

ABSTRACT

Background: Most displaced supracondylar humerus fractures (SCHFs) are treated with closed reduction and percutaneous pinning. While there are only a few possible indications for converting to an open reduction, a failed closed reduction is a common cause. This study aims to elucidate possible risk factors for failed closed reductions of SCHF.

Methods: A retrospective review of SCHF from 2010 to 2020 at a pediatric tertiary medical center, which underwent operative fixation, was conducted. Exclusion criteria were open fractures and reasons for open reduction other than failed closed reduction. Rates of open reduction were assessed by preoperative fracture classification and assessed for respective associations with the factors of interest using Student's t-test, χ^2, or Fisher exact tests as indicated.

Results: Seven hundred sixteen patients (age range 1-15 years old) met the inclusion criteria. Failed closed reductions were more likely in flexion-type fractures (15/37) compared to type III extension fractures (31/480) (OR: 9.88, 95% CI: 4.66-20.92). For flexion-type fractures, failed closed reduction occurred at a lower rate for anteriorly displaced fractures (5/22) when compared to other displacement directions (10/15) (OR: 0.15, 95% CI: 0.034-0.637). Age, race, social deprivation index, BMI, associated injuries, comminution, and nerve palsy were not significant. For type III extension fractures, older age (> 8 years) (OR: 5.22, 95% CI: 1.56-17.43) and nerve injury (OR: 2.23, 95% CI: 1.00-5.10) were associated with failed closed reduction. No other factors of interest were significant.

Conclusions: Flexion-type SCHFs have significantly higher rates of failed closed reduction compared to extension-type fractures. For flexion-type fractures, anterior displacement predicts a lower rate of failed closed reduction compared to other displacement directions. For type III extension fractures, risk factors include older age and a nerve injury on preoperative exam.

Key concepts:

(1) Most operative supracondylar humerus fractures (SCHFs) can be treated with closed reduction and percutaneous pinning.
(2) Surgeons need to be aware of possible reasons for having to convert to open reduction of pediatric SCHFs.
(3) Flexion-type fracture patterns had a higher rate of an open procedure compared to extension-type fractures.
(4) Patients who sustained an extension-type injury were more likely to require an open reduction if they had a nerve injury or were older at the time of injury or pinning (> 8 years old).

Level of Evidence: III, Retrospective Cohort Study

* Corresponding author: 14 S. Planchard Cir., The Woodlands, TX 77382, USA.
E-mail address: Pablo.Coello@bcm.edu (P. Coello).

https://doi.org/10.1016/j.jposna.2024.100079
Received 13 March 2024; Received in revised form 27 June 2024; Accepted 27 June 2024
Available online 15 July 2024

Introduction

Supracondylar humerus fractures (SCHFs) are very common injuries in pediatric orthopaedics [1]. Current guidelines largely rely on Gartland classification to determine the initial treatment of patients with SCHF [2]. The standard of care for operative SCHF is closed reduction and percutaneous pinning. However, closed reduction and percutaneous pinning can fail, requiring conversion to open reduction and pinning or other instrumentation [3].

Certain fracture classifications have been previously associated with an increased risk of failed closed reduction, such as Gartland III and Flexion-type fractures [4,5]. Certain concomitant injuries, such as neurovascular complications, marked displacement, and fragment instability, are established indications for prompt operative treatment and also correlate with failure during closed reduction attempts [5–7]. Some studies have identified a delay in fracture treatment as a factor in conversions to open reduction [8–12], as well as an age greater than 8 years old. Obesity, non-White, and lower socioeconomic status have also been found to be significant risk factors in several studies [4,7,13–16].

Initial treatment with closed reduction techniques is less invasive, cost-effective, and associated with shorter procedural times [17]. However, certain fracture types, such as type III Gartland fractures, have a higher rate of undergoing open treatment.

While long-term outcomes of open versus closed reduction with percutaneous pinning of SCHF are similar, correctly identifying the optimal initial treatment helps better inform families as well as reduces operational costs and patient discomfort, among other benefits [18]. Importantly, better characterization of factors that correlate with failure of closed reduction can allow a surgeon to more adequately anticipate an open procedure, allowing for proper equipment, room preparation, and critical preoperative planning to take place. Current guidelines for fracture patterns of moderate severity are not firm, and physicians sometimes resort to anecdotal evidence when determining whether to proceed with open treatment [18]. Therefore, the purpose of this study is to characterize various risk factors in the context of Gartland type III or flexion type for failed closed reduction of SCHF, making preoperative planning more reliable.

Materials and methods

A retrospective review of operatively managed SCHF from 2010 to 2020 at a tertiary pediatric medical center was conducted after Institutional Review Board approval. Inclusion criteria were operative management for SCHF and chart availability of fracture type, imaging availability, patient demographic data (age, race, social deprivation index [SDI], and BMI), displacement direction, presence of comminution, presence of associated injuries, and nerve palsy at time of initial presentation. The presence of comminution and direction of displacement were determined by the primary surgeon on a case-by-case basis. Exclusion criteria were open fractures and reasons for open reduction other than failed closed reduction, such as vascular compromise. Rates of open reduction were assessed and analyzed by fracture type. Fracture type was determined by radiographs and operative notes. Fracture types assessed included type III and flexion type. Type II fractures were excluded. The remaining type III and flexion supracondylar fractures were then assessed for their respective associations with the factors of interest. Type III supracondylar fractures determined to be type IV intraoperatively were not present within the study population. Quantitative variables were analyzed using Student's t-test, and qualitative variables were assessed using χ^2 or Fisher exact tests.

Results

Seven hundred sixteen patients (age range 1-15 years old) identified via retrospective chart review met all inclusion criteria. Twenty-six were excluded due to open fractures or indications for open reduction other than failed closed reduction. Failed closed reduction was more likely in flexion-type fractures (15/37, 40.5%) compared to type III fractures (31/480, 6.45%) (OR: 9.88, 95% CI: 4.66-20.92) (Table 1). For flexion-type fractures, demographic factors including average age, BMI, and SDI, percent non-White, and non-English speakers were not different between closed and open reduction groups. Associated injuries, comminution, and nerve palsy were also found not to be significant (Table 2).

Only 5 patients presented with a flexion-type supracondylar fracture and concurrent nerve palsy. Of these, 3 proceeded to open reduction.

Table 1
Rates of open reduction by fracture type.

Fracture classification	Open reduction (*n*, %)	Closed reduction (*n*, %)	Total	odds ratio (95% CI)	*P* value
Total	46 (8.9%)	471 (91%)	517	-	-
Type III	31 (6.4%)	449 (94%)	480	-	*
Flexion	15 (41%)	22 (59%)	37	9.88 (4.66, 20.9)*	< .0001

* Comparing type III and flexion-type fractures.

Table 2
Factors of interest in failed closed reductions of flexion-type fractures.

	Flexion fractures			
	Open reduction (*n*, %)	Closed reduction (*n*, %)	Odds ratio (95% CI)	*P* value
Total (% of total)	15 (41%)	22 (59%)	-	-
Average age	8.87 ± 0.78	8.64 ± 1.21	-	.77
Average BMI	18.97 ± 2.11	18.34 ± 1.47	-	.6
Average SDI	47.13 ± 19.3	44.05 ± 13.9	-	.78
Non-White (% of total)	6/15 (40%)	10/22 (45%)	-	.74
Non-English (% of total)	2/15 (13%)	4/22 (18%)	-	.69
Comminuted	3/15 (20%)	0/22 (0%)	-	.06
Nerve injury, motor & sensory	3/15 (20%)	2/22 (9.1%)	-	.38
Nerve injury, sensory only	2/15 (13%)	1/22 (4.5%)	-	.94
Associated injury (y/n)	0/15 (0%)	1/22 (4.5%)	-	.4

SDI, social deprivation index; BMI, Body mass index.

Table 3
Rates of failed closed reduction by fracture displacement direction in flexion-type fractures.

	Displacement direction of flexion fractures				
	Open reduction (*n*, %)	Closed reduction (*n*, %)	Total	Odds ratio (95% CI)	*P* value
Total	15 (41%)	22 (59%)	37	-	-
Anterior	6 (26%)	17 (74%)	23	0.20 (0.03, 0.63)	.02
Anterolateral	6 (55%)	5 (45%)	11	-	.30
Anteromedial	2 (100%)	0 (0%)	2	-	.41
Medial	1 (100%)	0 (0%)	1	-	.41

Table 4
Factors of interest in failed closed reductions of Gartland type III fracture types.

	Type III fractures			
	Open reduction (*n*, %)	Closed reduction (*n*, %)	Odds ratio (95% CI)	*P* value
Total (% of total)	31 (6%)	480 (94%)	-	-
Average age	8.61 ± 0.49	7.45 ± 0.25		.02†
Average BMI	18.83 ± 2.79	19.42 ± 3.76	-	.94
Average SDI	49.53 ± 12.1	50.48 ± 3.00	-	.92
Non-White (% of total)	18/31 (58%)	276/449 (61%)	-	.71
Non-English (% of total)	7/31 (23%)	80/480 (17%)	-	.51
Comminuted	5/31 (16%)	40/449 (8.9%)	-	.18
Nerve injury, motor & sensory	9/31 (29%)	69/449 (15%)	2.23 (1.0-5.10)	.046†
Nerve injury, sensory only	1/31 (3%)	23/449 (5.1%)	-	.69
Associated injury (y/n)	0/31 (0%)	15/449 (3.3%)	-	.3

SDI, social deprivation index.

Table 5
Rates of failed closed reduction by direction of fracture displacement in Gartland type III fractures.

	Displacement direction of type III fractures				
	Open reduction (*n*, %)	Closed reduction (*n*, %)	Total	Odds ratio (95% CI)	*P* value
Total	31 (7%)	449 (93%)	480	-	-
Posterior	2 (4%)	47 (96%)	49	-	.76
Posterolateral	14 (6%)	221 (94%)	235	-	.71
Posteromedial	15 (8%)	181 (92%)	196	-	.71

One patient with a flexion-type fracture presented with an associated fracture (olecranon fracture) and required open reduction. Conversion to open reduction occurred at a significantly lower rate for purely anteriorly displaced fractures (6/23, 26.0%) when compared to other displacement directions, including anterolateral, anteromedial, and medial (10/15, 66.7%) (P = .02, OR: 0.15, 95% CI: 0.034-0.637) (Table 3). Older patients (> 8 years old) in Gartland type III fractures were significantly associated with failed closed reduction (P = .020). No other demographic factors were significantly associated with failed closed reduction. The presence of nerve palsy on a preoperative exam was associated with failed closed reduction (OR: 2.25, 95% CI: 1.00-5.10) (Table 4). Associated injuries and the presence of comminution were not significant. Fracture displacement direction was also not significant (Table 5).

Discussion

This study found that flexion-type fractures were significantly more likely to require open reduction. Purely anterior displacement in patients with flexion-type fractures was found to be protective against failed closed reduction. In patients with Gartland type III fractures, older patients (> 8 years old) and a coexisting nerve injury (both motor and sensory components) were found to be significant risk factors for failed closed reduction.

Past studies have demonstrated that risk factors for conversion to open reduction include Gartland III fracture classification, larger initial displacement, and associated ulnar nerve injuries [4–7,15]. Flexion-type fractures have also been identified as risk factors for open reduction [5,19,20]. In contrast, many remaining potential risk factors, such as BMI or age, have also been studied, but results have been inconclusive, warranting further investigation [4,7,14,15].

This study found flexion-type fractures were more likely to be open compared to type III fractures, with an OR of 9.88 (95% CI: 4.66, 20.9). This agrees with other studies and may be due to the inherent instability that exists within flexion-type fractures during closed reduction with disruption of the medial column and loss of the posterior periosteal hinge [5,15,19,20]. To our knowledge, this is the first study to analyze flexion-type fractures by direction of displacement and show that flexion-type fractures with purely anterior displacement upon initial radiographic evaluation exhibited a lower risk of proceeding to open reduction. The most common method of closed reduction for flexion-type fractures involves placing the elbow in extension while correcting rotational malalignment [21]. It is likely that flexion-type fractures displaced in any direction other than purely anterior create a fracture geometry that is more unstable, requiring further manipulation in additional planes to achieve reduction. Limited literature exists regarding the displacement direction of flexion-type fractures and resulting rates of failed closed reduction of SCHF. The findings in this study indicate this may be worth further analysis, especially when considering the effect size of anterior fracture displacement (OR = 0.20, [95% CI: 0.034, 0.637]), which may influence physician decision-making during preoperative planning. With regard to Gartland III fractures, the general anatomy surrounding the fracture, as well as the usual lack of cortical contact and detached periosteum, make this

fracture type particularly challenging to close and reduce [4]. In this study, however, type III fracture classification itself was not determined to be a significant risk factor for failed closed reduction when compared to flexion type.

Other factors for open reduction that were considered were older age (> 8 years old), BMI, fracture type, concurrent nerve palsy, as well as socioeconomic factors such as SDI, race, and primary language. Fletcher et al. also found in that in type III fractures, age older than 8 was a significant predictor of failed closed reduction. It has been previously suggested that exposure to higher energy mechanisms and or more prominent musculature in older children may play a role in describing the relationship between age and progression to open reduction internal fixation [13,15]. Therefore, it may be that these mechanisms more often lead to type III fractures, explaining the link between age and failed closed reduction. However, in the specific context of flexion-type fractures, our study found that age was not a significant predictor of failed closed reduction, with the mean ages between the open and closed reductions of SCHF differing only by approximately 84 days (Table 2). This generally agrees with the available literature, and it has been suggested that skeletal age rather than calendar age is more relevant in flexion fractures [15,22]. Regarding BMI, no increased risk for open reduction internal fixation was found for any fracture type, which coincides with some available literature [4,7,15].

Nerve palsy, specifically ulnar nerve palsy, has been shown to increase the risk of progression to open reduction [5,15]. In this study, patients presenting with nerve palsy in flexion-type fractures were not at increased risk for failed closed reduction. In contrast, concurrent nerve palsy in patients with type III fractures did show a significantly increased risk of failed closed reduction. More specifically, extension-type III fractures displayed an increased risk of failed closed reduction in patients with both motor and sensory deficits on presentation but not when considering sensory deficits only. This suggests more significant nerve injuries accompany increased rates of open fracture reductions. It has been previously suggested that nerve palsy occurs more frequently in higher energy mechanisms [23]. Higher energy mechanisms generally result in more significant disruptions of native anatomy, which make a fracture more difficult to successfully reduce closed and lead to increased risk of nerve injury. Therefore, the presence of nerve injury likely indicates that the presence of fracture geometry is less favorable to reduce closed.

Lastly, this study looked at the impacts of several socioeconomic factors, including race, English as a first language, and the SDI. The SDI is a tool used to estimate the cumulative impact of many socioeconomic variables, such as income, race, education, etc. on health outcomes [24]. The rationale behind examining this variable was previous research indicating a connection between socioeconomic factors and bone health in pediatric patients and subsequent lack of evidence regarding specific health outcomes [25]. In flexion and type III SCHFs, language spoken, race, and SDI were not significant risk factors for failed closed reduction.

Limitations

This study had a few limitations. First, this was a retrospective cohort study, limiting conclusions to associations. This study design also suffers from the possibility of inconsistent documentation, which may affect the calculated rates of concurrent injuries or reasons why a fracture was open. Where needed, the primary surgical team was consulted for clarifying information. Further, flexion-type supracondylar fractures were relatively rare within the study population. As a result, a few potential risk factors, such as comminution, were seen in very limited quantities, making it difficult to draw conclusions on those factors.

Conclusion

Type III and flexion-type fractures appear to have different risk factors for failed closed reduction. In type III SCHFs, older age (> 8 years) and nerve injury at presentation are risk factors for failed closed reduction. Flexion-type SCHFs have significantly higher rates of failed closed reduction compared to extension-type fractures. For flexion-type fractures, purely anterior displacement on injury films required a lower rate of failed closed reduction compared to other displacement directions. Given the lack of literature in this specific area and the potential benefits surgeons have in their preoperative planning, it is important to further describe the relationship between displacement direction and failed closed reduction of SCHFs.

Additional links

- POSNAcademy: Open Approach to Supracondylar Humerus Fractures
- POSNAcademy: IPOS® 2021: Type 4 Supracondylar Humerus Fractures - Made Easy

Funding

No funding was received.

Ethics approval and consent

The authors confirm that this study received Institutional Review Board Approval (H-45616) with appropriate consents, permissions, and releases obtained from patients and/or guardians. Patient confidentiality was preserved during the study, and no patient-identifiable data was reported in the manuscript.

Author contributions

Pablo Coello: Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Nathaniel Grey Loyd:** Writing – original draft, Investigation, Formal analysis, Conceptualization. **David A. Hsiou:** Writing – original draft, Data curation. **Rachel S. Silverstein:** Writing – review & editing, Validation, Supervision. **Scott B. Rosenfeld:** Writing – review & editing, Validation, Supervision.

Declarations of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Baig M. A review of epidemiological distribution of different types of fractures in paediatric age. Cureus 2017;9:e1624. https://doi.org/10.7759/cureus.1624.
[2] Micheloni GM, Novi M, Leigheb M, Giorgini A, Porcellini G, Tarallo L. Supracondylar fractures in children: management and treatment. Acta Bio Med Atenei Parm 2021;92(Suppl 3):e2021015. https://doi.org/10.23750/abm.v92iS3.11725.
[3] Pirone AM, Graham HK, Krajbich JI. Management of displaced extension-type supracondylar fractures of the humerus in children. JBJS 1988;70:641.
[4] Sun LJ, Wu ZP, Yang J, Tian N-F, Yu X-B, Hu W, et al. Factors associated with a failed closed reduction for supracondylar fractures in children. Orthop Trauma Surg Res 2014;100:621–4. https://doi.org/10.1016/j.otsr.2014.05.015.
[5] Flynn K, Shah AS, Brusalis CM, Leddy K, Flynn JM. Flexion-type supracondylar humeral fractures: ulnar nerve injury increases risk of open reduction. J Bone Jt Surg 2017;99:1485–7. https://doi.org/10.2106/JBJS.17.00068.
[6] Beck JD, Riehl JT, Moore BE, Deegan JH, Sartorius J, Graham J, et al. Risk factors for failed closed reduction of pediatric supracondylar humerus fractures. Orthopaedics 2012;35:e1492–6. https://doi.org/10.3928/01477447-20120919-18.
[7] Ondina AB, Haidar LA, Goldberg B, Mansour III A, Younas S, Siahaan J, et al. Factors associated with conversion to open reduction of type 3 supracondylar humerus fractures in children. J Clin Orthop Trauma 2022;30:101893. https://doi.org/10.1016/j.jcot.2022.101893.
[8] Gupta N, Kay RM, Leitch K, Femino JD, Tolo VT, Skaggs DL. Effect of surgical delay on perioperative complications and need for open reduction in supracondylar humerus fractures in children. J Pedia Orthop 2004;24:245–8. https://doi.org/10.1097/00004694-200405000-00001.

[9] Loizou CL, Simillis C, Hutchinson JR. A systematic review of early versus delayed treatment for type III supracondylar humeral fractures in children. Injury 2009;40:245–8. https://doi.org/10.1016/j.injury.2008.07.031.
[10] Mehlman CT, Strub WM, Roy DR, Wall EJ, Crawford AH. The effect of surgical timing on the perioperative complications of treatment of supracondylar humeral fractures in children. J Bone Jt Surg Am Vol 2001;83:323–7. https://doi.org/10.2106/00004623-200103000-00002.
[11] Okkaoglu MC, Ozdemir FE, Ozdemir E, Karaduman M, Ates A, Altay M. Is there an optimal timing for surgical treatment of pediatric supracondylar humerus fractures in the first 24 hours? J Orthop Surg 2021;16:484. https://doi.org/10.1186/s13018-021-02638-5.
[12] Walmsley PJ, Kelly MB, Robb JE, Annan IH, Porter DE. Delay increases the need for open reduction of type-III supracondylar fractures of the humerus. J Bone Jt Surg Br 2006;88-B:528–30. https://doi.org/10.1302/0301-620X.88B4.17491.
[13] Fletcher ND, Schiller JR, Garg S, Weller A, Noelle Larson A, Kwon M, et al. Increased severity of type III supracondylar humerus fractures in the preteen population. J Pedia Orthop 2012;32:567–72. https://doi.org/10.1097/BPO.0b013e31824b542d.
[14] Çabuk H, Dedeoğlu SS, Adaş M, Tekin AÇ, Seyran M, Ayanoğlu S. Medial spike and obesity associate with open reduction in type III supracondylar humeral fracture. Acta Chir Orthop Trauma Cech 2016;83:102–5.
[15] Sun J, Shan J, Meng L, Liu T, Wang E, Jia G. Predictive factors for open reduction of flexion-type supracondylar fracture of humerus in children. BMC Musculoskelet Disord 2022;23:859. https://doi.org/10.1186/s12891-022-05798-5.
[16] Montgomery BK, Joseph G, Segovia N, Koltsov J, Thomas TL, Vorhies JS, et al. The influence of race, income, and sex on treatment and complications of common pediatric Orthopaedic fractures. Orthopaedics 2023;46:e156–60. https://doi.org/10.3928/01477447-20230104-06.
[17] Laxdal I, Stockwell K, Xu M, Tan J, McRae S, Jellicoe P. Supracondylar fractures: a retrospective chart review comparing infection rate, antibiotic use, surgical time and cost of full surgical preparation and draping vs “Semi-Sterile” technique. Orthop Res Rev 2020;12:183–8. https://doi.org/10.2147/ORR.S268517.
[18] Mahan ST, Miller PE, Park J, Sullivan N, Vuillermin C. Fully displaced pediatric supracondylar humerus fractures: which ones need to go at night? J Child Orthop 2022;16:355–65. https://doi.org/10.1177/18632521221119540.
[19] Latario LD, Lubitz MG, Narain AS, Swart EF, Mortimer ES. Which pediatric supracondylar humerus fractures are high risk for conversion to open reduction? J Pedia Orthop B 2023;32:569–74. https://doi.org/10.1097/BPB.0000000000001042.
[20] Novais EN, Carry PM, Mark BJ, De S, Miller NH. Posterolaterally displaced and flexion-type supracondylar fractures are associated with a higher risk of open reduction. J Pedia Orthop B 2016;25:406–11. https://doi.org/10.1097/BPB.0000000000000314.
[21] De Boeck H. Flexion-type supracondylar elbow fractures in children. J Pedia Orthop 2001;21:460–3.
[22] Bekmez S, Camp MW, Ling R, El-Amiri N, Howard AW. Supracondylar humerus fractures in older children: success of closed reduction and percutaneous pinning. J Pedia Orthop 2021;41:242–8. https://doi.org/10.1097/BPO.0000000000001732.
[23] Delniotis I, Dionellis P, Gekas CC, Arapoglou D, Tsantekidis D, Goulios V, et al. Flexion-type supracondylar humeral fracture with ulnar nerve injury in children: two case reports and review of the literature. Am J Case Rep 2020;21:e921293. https://doi.org/10.12659/AJCR.921293.
[24] Butler DC, Petterson S, Phillips RL, Bazemore AW. Measures of social deprivation that predict health care access and need within a rational area of primary care service delivery. Health Serv Res 2013;48:539–59. https://doi.org/10.1111/j.1475-6773.2012.01449.x.
[25] Beck JJ, Mahan ST, Nowicki P, Schreiber VM, Minkowitz B. What is new in pediatric bone health. J Pedia Orthop 2021;41:e594–9. https://doi.org/10.1097/BPO.0000000000001896.