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ORIGINAL ARTICLE

Surgical treatment of pediatric supracondylar humerus fracture could be safely performed by general orthopedists

P. Osateerakun[1,2] · I. Thara[1] · N. Limpaphayom[1]

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Abstract

Purpose Displaced pediatric supracondylar humerus fracture (SCHF) requires a reduction and instrumentation. The trend is to send the cases to a fellowship-trained pediatric orthopedist. This study reviewed the outcomes and complications of SCHF surgically managed by orthopedic surgeons with different backgrounds of subspecialty training.

Methods The medical records of 87 children (87 elbows) with an average age of 5.9 ± 3.1 (range 1.3–14.1) years with SCHF Gartland 2 and 3 who underwent operative fixation were reviewed. The demographics data and operative details were obtained. Radiographically, the Baumann and humerocapitella angles were measured. The lateral rotational percentage of Gordon was calculated. The Griffet index 1 and 2 were retrieved. The parameters were compared among groups of surgeons with a pediatric fellowship-trained background and surgeons with other subspecialty training. A univariate analysis was calculated for the risk of postoperative complications.

Results The demographics data were comparable between the two groups. Children who were treated by non-pediatric fellowship-trained orthopedists showed higher but not significant degrees of postoperative Baumann angles; however, the proportion of children with an acceptable range of Baumann angle were similar. The overall complications rate was 17.5% and comparable between the two groups. Only SCHF Gartland 3 was associated with complications ($P = 0.01$).

Conclusions Pediatric SCHF could be efficiently managed by a general orthopedic surgeon because the radiographic outcomes and complications were comparable to pediatric fellowship-trained orthopedists. Extra precautions need to be exercised in SCHF Gartland type 3 because the chance of complications is higher among these types of injuries.

Level of evidence Level III.

Keywords Child · Outcomes · Postoperative complication · Radiograph · Surgery · Supracondylar

Introduction

Supracondylar humerus fracture (SCHF) is one of the most common injuries in children. The accepted treatment method of displaced SCHF is anatomic reduction; this is preferably done by a closed method, although the need to perform an open reduction procedure could be as high as in a 20% range [1]. The accepted overall complications rate was 5–20% [1].

The evolving trend of treatment is to transfer children with SCHF to fellowship-trained pediatric orthopedist [1]. This practice may provide a faster treatment and a shorter hospital stay [1]. However, in some areas, the availability of pediatric orthopedic specialty is lacking. Several reports indicated that an excellent outcome could be achieved by general orthopedic surgeons who were confident in treating such a fracture. Moreover, the method of treatment, outcomes and complications rate were similar between pediatric fellowship-trained orthopedists and orthopedic surgeons with different backgrounds of subspecialty training [2, 3].

Different treatment algorithms are based on several factors [2–7]. The treatment algorithm may not be considered ideal in certain circumstances, e.g., the limited operative room time allocation may preclude the treatment in the first 12–24 h after injury [4, 8, 9]. It could reflect the reality in many parts of the world where a discrepancy between the

✉ N. Limpaphayom
Noppachart.L@chula.ac.th

[1] Department of Orthopaedics, Faculty of Medicine, Chulalongkorn University, Pathumwan, Bangkok 10330, Thailand

[2] Department of Orthopaedics, King Chulalongkorn Memorial Hospital, Thai Red Cross Society, Bangkok, Thailand

services needed and the physicians remain. Despite the best effort of the responding orthopedists in taking care of pediatric SCHF, complications do occur.

We reviewed the outcomes of surgically managed pediatric SCHF assessed by radiographic measurements and postoperative complications. We determined whether the results between pediatric fellowship-trained orthopedists were different compared to those by orthopedic surgeons with different subspecialties.

Materials and methods

The medical review of surgically treated pediatric SCHFs at a university-based medical center was performed after ethical approval was granted. We included only SCHF Gartland type 2 and 3 without an open wound or associated with vascular injury to our review.

Routine treatment protocol

All orthopedic faculties share a trauma service call regardless of their subspecialty training. The operative theaters are shared among orthopedic specialties including elective and emergency cases during the daytime. The operative theaters are shared by every surgical department during non-office hours.

Displaced SCHF would be gently reduced as much as possible in an emergency department, immobilized in a long-arm splint and admitted to the ward. SCHFs were operated on an urgent or elective basis depending on the availability of the operating room, apart from an open injury or an injury associated with suspected vascular compromise. Once in the operating room, an attempted close reduction was performed under an image intensifier-controlled followed by an open reduction if necessary. Choices of reduction method, Kirschner wire (K-wire) configuration and numbers of K-wire were at the discretions of the attending surgeons. After the operation, the elbow was immobilized in a long-arm splint. Intravenous antibiotic was given for a 24-h period. K-wires were removed at 4–6 weeks post-operation. No formal physical therapy was prescribed. All children were followed regularly at 36-month intervals.

The demographic data including gender, age at injury, elbow side and body mass index (BMI) were obtained. Details of operative treatment obtained were operative wait time (days), estimated blood loss (mL), operative time (minutes), duration of follow-up (weeks), reduction method and K-wire configuration and number. The preoperative anteroposterior (AP) and lateral (Lat) radiographs were reviewed, and the fractures were classified according to the Gartland classification. The lateral rotational percentage was calculated according to the method described by Gordon on the immediate post-healing radiograph—usually at 4–6 weeks postoperative [10]. The Griffet index 1 and Griffet index 2 were calculated as previously described [11]. At the most recent evaluation, the following radiographic parameters were obtained. The Baumann angle was measured on the AP film [11, 12]. The number of children whose postoperative films had the accepted range of Baumann angle of 65°–81° and those who did not was recorded [13]. The humerocapitella angle was measured on the Lat film [11]. All radiographs were evaluated by a single observer (NL). Complications after surgical treatment were recorded, and the overall complications rate was calculated. A minor complication was an event that required only an expectant treatment, such as local wound irrigation or oral antibiotics. A major complication was defined as an event that required a re-operation or a surgical treatment.

The surgeons were grouped according to their orthopedic specialty training. Group 1 is composed of surgeons with fellowship training in any other orthopedic specialties. This group had 6 surgeons with the following subspecialty training: adult reconstruction ($n=2$), hand and microvascular ($n=1$), spine ($n=2$) and sport medicine ($n=1$). Group 2 is composed of 2 pediatric orthopedists. All parameters were compared among the two surgeon groups.

Statistical analysis was performed using Stata 13 (Stata Corp LP, College Station, TX, USA) Continuous data were reported using mean ± standard deviation (SD) and range. Categorical data were reported using number and percent, when appropriate. Student's *t* test was used to compare continuous data, and Chi-square (χ^2) test was used to compare categorical data between the two groups. A univariate analysis was calculated to identify parameters associated with the complications. *P* value of less than 0.05 was considered statistically significant. This study was approved by an ethical review board of the Faculty of Medicine, Chulalongkorn University, Thailand, COA 287/2017, dated April 18, 2017, and complied with the declaration of Helsinki and its later amendments. For this type of study, a formal consent is not required per the regulations set by the ethical review board of the institution.

Results

During January 2005–December 2016, 87 children (87 elbows) with an average age of 5.9 ± 3.1 (range 1.3–14.1) years were operatively treated for a supracondylar humerus fracture. They were classified as Gartland type 2 in 33 and type 3 in 54 elbows. The demographic data are presented in Table 1. Quality of reduction as assessed by 5 radiographic parameters is presented in Table 2. The Baumann angle in non-pediatric orthopedic group demonstrated a value toward more varus alignment. Although there was a statistically

Table 1 Demographic data of the 87 children with supracondylar humerus fracture undergoing a surgical treatment

	Total ($n=87$)	%	Non-Ped ($n=26$)	Ped ($n=61$)	*P*
Gender					
Boy	60	69	20	40	0.29
Girl	27	31	6	21	
Age	5.86 ± 3.1 (1.2–14.1)		5.96 ± 2.8 (1.9–11.1)	5.82 ± 3.2 (1.2–14.1)	0.85
Side					
Right	33	38	9	24	0.68
Left	54	62	17	37	
BMI (kg/m^2)	17.39 ± 4.2 (11.1–29.3)		18.4 ± 4.9 (12.5–29.3)	16.9 ± 3.8 (11.1–26.6)	0.14
Op-wait time (days)	2.16 ± 2.4 (0.02–14.7)		1.74 ± 1.8 (0.02–5.5)	2.34 ± 2.6 (0.02–14.7)	0.29
EBL (ml)	39.47 ± 57.3 (1–300)		30.69 ± 42.8 (1–200)	43.21 ± 62.4 (1–300)	0.35
Op-time (min)	75.78 ± 36.6 (20–160)		70.69 ± 29.3 (23–120)	77.95 ± 39.3 (20–160)	0.40
Duration of follow-up (months)	6.50 ± 16.5 (1.1–134.6)		5.27 ± 10.9 (1.1–57.2)	7.03 ± 18.4 (1.1–134.6)	0.65
Classification and reduction method					
2-CR	23		5	18	0.28
3-CR	13		5	8	
2-OR	10		4	6	0.51
3-OR	41		12	29	
Classification and configurations of K-wire					
2-lat	20		3	17	0.11
2-cross	13		6	7	
3-lat	12		3	9	0.73
3-cross	42		14	28	
Number of K-wires					
2	32	37	14	18	0.13
3	51	59	12	39	
4	3	3	0	3	
6	1	1	0	1	

Classification was based on the system of Gartland. Data were presented as mean ± standard deviation (range) or number, as appropriate

BMI, body mass index; CR, close reduction; cross, cross-pin configuration; EBL, estimated blood loss; K-wire, Kirschner wire; lat, lateral pin configuration; Non-Ped, non-pediatric orthopedics surgeon; op, operative; OR, open reduction; Ped, pediatric orthopedics surgeon

significant difference between the mean of Baumann angle between both groups of surgeons, the value in both groups was in a normal reference range. The complications occurred in 17 elbows with an overall complication rate of 17.5%. From the univariate analysis, children with SCHF Gartland type 3 were prone to having postoperative complications. Complications were not associated with level of subspecialty training of the orthopedic surgeons (Table 3). Minor complication involved 15 elbows where the expectant treatment resulted in an uneventful recovery. Two elbows required a re-operation and were classified as a major complication (Table 4).

We observed a rare major complication in one elbow which septic arthritis complicated a percutaneous K-wire insertion procedure combined with radial nerve laceration from a K-wire. The patient was a 3-year-old girl with SCHF Gartland type 2 of the right elbow (Fig. 1a, b). She underwent a close reduction and percutaneous K-wires fixation with lateral-entry technique (Fig. 1c, d). Radial nerve palsy was detected after the operation. The right elbow became warm and swollen and did not respond to K-wire removal, local wound care and oral antibiotics (Fig. 1e, f). An open debridement of septic arthritis was scheduled (Fig. 1g). The radial nerve was lacerated by the lateral-most K-wire, and

Table 2 Radiographic parameters of the 87 children with supracondylar humerus fracture after the surgical treatment

	Total ($n=87$)	Non-Ped ($n=26$)	Ped ($n=61$)	*P*
Baumann angle	72.7 ± 6.6 (57–90)	74.9 ± 6.8 (61.0–90.0)	71.7 ± 6.3 (57.0–90.0)	0.04
Baumann angle < 65° or > 81° [13]	16/87	6/26	10/61	0.46
Humerocapitella angle	41.1 ± 8.3 (11–62)	39.3 ± 12.4 (11–62)	41.6 ± 6.7 (23–59.1)	0.30
Gordon index [10]	2.54 ± 6.9 (0–35.5)	3.4 ± 7.1 (0–21.7)	2.3 ± 6.9 (0–35.5)	0.56
Griffet index 1 [11]	1.08 ± 0.1 (0.7–1.5)	1.1 ± 0.2 (0.8–1.5)	1.1 ± 0.1 (0.7–1.4)	0.89
Griffet index 2 [11]	1.33 ± 0.7 (0.7–4.5)	1.4 ± 0.8 (0.8–3.3)	1.3 ± 0.7 (0.9–4.5)	0.58

Data were presented as mean ± standard deviation (range) or number, as appropriate

Non-Ped, non-pediatric orthopedics surgeon; Ped, pediatric orthopedics surgeon

Table 3 Data of children with and without complications after surgical treatment of supracondylar humerus fracture

	No complication ($n=70$)	Complication ($n=17$; 19.5%)	*P*
Surgeon			
Non-Ped	19	7	0.26
Ped	51	10	
Gender			
Boy	50	10	0.31
Girl	20	7	
Age	6.1 ± 3.2 (1.2–14.1)	4.9 ± 2.7 (1.4–10.5)	
Side			
Right	28	5	0.42
Left	42	12	
Classification			
2	31	2	0.01
3	39	15	
Op-wait time (days)	2.3 ± 2.6 (0.1–14.7)	1.7 ± 1.3 (0.1–4.8)	0.41
Duration of follow-up (months)	5.7 ± 16.1 (1.1–134.6)	9.8 ± 18.1 (1.1–57.2)	0.37
BMI (kg/m^2)	17.6 ± 4.4 (11.1–29.3)	16.7 ± 3.3 (12.8–23.9)	0.44
EBL (ml)	36.2 ± 50.9 (1–200)	53.1 ± 79.0 (1–300)	0.28
Op-time (min)	73.9 ± 36.5 (20–160)	83.2 ± 37.5 (25–150)	0.35
Reduction method			
CR	31	5	0.26
OR	39	12	
Number of K-wires			
2	25	7	0.78
3	41	10	
4	3	0	
6	1	0	
Configuration of K-wire			
Lat	27	5	0.48
Cross	43	12	

Classification was based on the system of Gartland. Data were presented as mean ± standard deviation (range) or number, as appropriate

BMI, body mass index; CR, close reduction; cross, cross-pin configuration; EBL, estimated blood loss; K-wire, Kirschner wire; lat, lateral pin configuration; Non-Ped, non-pediatric orthopedics surgeon; op, operative; OR, open reduction; Ped, pediatric orthopedics surgeon

Table 4 Details of children with complications after surgical treatment of supracondylar humerus fracture

	Gender	Side	Classification	Reduction	Surgeon	Complications	Management
Minor							
1	Girl	L	2	OR	Ped	Superficial wound infection	Wound care, oral antibiotics
2	Boy	L	2	OR	Non-Ped	K-wire tract infection	Local wound care, oral antibiotics
3	Boy	L	3	OR	Ped	1. K-wire infection and loosening 2. Ulna nerve palsy by hardware	1. K-wire removal, oral antibiotics 2. Observation
4	Girl	L	3	OR	Ped	K-wire tract infection	Local wound care, oral antibiotics
5	Boy	L	3	CR	Non-Ped	Superficial wound infection	Wound care, oral antibiotics
6	Boy	L	3	CR	Ped	1. K-wire tract infection 2. Preoperative radial nerve palsy	1. Local wound care, oral antibiotics 2. Observation
7	Boy	L	3	OR	Ped	Medial K-wire loosening	K-wire removal, oral antibiotics
8	Boy	L	3	CR	Non-Ped	Deep wound infection	Wound irrigation, oral antibiotics
9	Boy	L	3	OR	Non-Ped	Deep wound infection	Wound irrigation, oral antibiotics
10	Girl	R	3	OR	Non-Ped	Suboptimal reduction	Observation
11	Girl	L	3	OR	Ped	1. Suboptimal reduction 2. Preoperative radial nerve palsy	Observation
12	Boy	R	3	OR	Ped	Suboptimal reduction	Observation
13	Girl	L	3	CR	Ped	Loss of reduction	Observation
14	Boy	R	3	OR	Ped	1. Suboptimal reduction 2. K-wire malposition	Observation
15	Girl	R	3	OR	Ped	K-wire malposition	Observation
Major							
16	Girl	R	3	CR	Non-Ped	1. Septic arthritis of the elbow 2. Radial nerve laceration from a K-wire	1. Open debridement 2. Repair of the nerve
17	Boy	L	3	OR	Non-Ped	Loss of reduction	K-wire revision

Classification was based on the system of Gartland

CR, close reduction; K-wire, Kirschner wire; L, left side; Non-Ped, non-pediatric orthopedics surgeon; OR, open reduction; Ped, pediatric orthopedics surgeon; R, right side

it was repaired (Fig. 1h, i). An uneventful recovery period was 12 weeks.

Discussion

The results of the study demonstrated that a selected group of pediatric SCHF could be effectively managed by a surgeon who acquired a general orthopedic training without the need for pediatric orthopedic fellowship training. The methods of fixations, qualities of fracture reduction and overall complication rates were comparable between the two groups.

It is the general trend that children suffering from SCHF will be sent to the Children Orthopaedic Center [1]. One of the main reasons was described to be a surgeon-on-duty in a primary care facility was specialization in other orthopedic specialties [7]. A fellowship-trained pediatric orthopedic becomes the norm in some parts of the world, but these surgeons may practice in a large general or an academic hospital; thus, this subspecialty-leveled surgeon may not be available in every geographical area [4, 7, 14]. There are many countries, including the country where this study was being conducted, listed as developing economies in a recent report by the United Nations, and they do not have these subspecialty-leveled surgeons in their remote parts [15]. Therefore, general orthopedic surgeons or other subspecialty-trained orthopedists are still responsible for this fracture in many local facilities [3–5]. Farley et al. [2] reported that non-pediatric orthopedic surgeons could manage this particular fracture effectively. In contrast, Lee et al. [3] reported that orthopedic surgeons with different subspecialty training backgrounds used a variety of protocol for the treatment of pediatric SCHF. Thus, the group urges a consensus on treatment algorithms and postoperative care plan. On the other hand, this present study supported the findings reported by Farley et al. [2]. Although a treatment guideline is not established at our institution, we did not find any significant difference between both groups in terms of method of treatment and radiographic outcomes. The number of complications was comparable between both groups.

In our cohort, most of the children were operated during office hour. SCHFs are typically treated as an urgent to

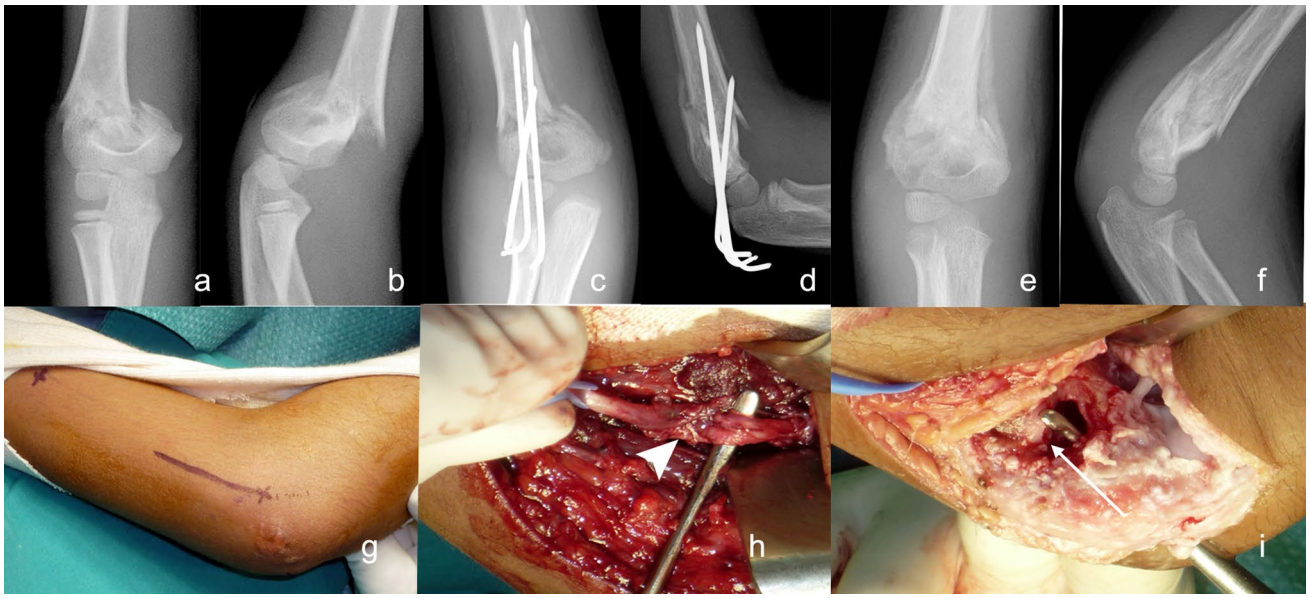

Fig. 1 Clinical photographs of a 3-year-old girl with right supracondylar humerus fracture Gartland type 2 who had a septic arthritis of the elbow joint and radial nerve laceration following a close reduction and percutaneous Kirschner wires (K-wire) fixation procedure. **a**, **b** Preoperative radiographs, **c**, **d** postoperative radiographs, **e**, **f** postoperative radiographs after K-wires were removed and demonstrated a soft tissue swelling, **g** a planned surgical debridement of the right elbow and exploration of the radial nerve, **h** an arrowhead indicated that there was a lacerated radial nerve, **i** an arrow indicated the tract of the lateral-most K-wire which injured the radial nerve

elective case that was supported by other reports [8, 9, 16]. Although these children had to wait for the operating room for more than 24 h, we were able to successfully treat SCHF in some of our children by a percutaneous instrumentation. However, a gentle close reduction and temporary immobilization should be performed in the emergency unit while waiting for availability of the operating room. This may not follow the current practice guidelines that the SCHF should be treated as an urgent case in order to obtain a successful close reduction. Yildirim et al. [6] showed that the necessity for an open reduction increased by fourfold every 5 h the reduction was postponed. On the contrary, Garg et al. reported that SCHF Gartland type 3 could be safely managed during routine office hours similar to our findings and that the physician's decision was the most important thing in influencing the outcome of the treatment [17]. Pullagura et al. [4] found that the rate of open reduction in their cohort is, on the other hand, higher for the children who were being treated within 6 h from initial injury. Nonetheless, timing of treatment did not affect the outcomes and complications of this study which corroborated the findings from a previous report.

Although the close reduction and percutaneous K-wire fixation for SCHF became standard practice, if the surgery needs to be delayed, an open reduction still provides acceptable clinical outcomes. However, it may lead to an increased chance of the procedure-related complications [13]. The type of open incision did not affect the clinical outcomes as shown in a recent report [18]. It is our preference to use a lateral approach and then add a medial incision if necessary. Guven et al. [19] confirmed that the cosmetic and function outcomes were excellent after an open reduction procedure, if properly perform, at an average of 22 years of follow-up. Furthermore, Simanovsky et al. [20] found that under-reduced SCHF could disturb the patient function and leave them a perceivable deficit in the long run. We, thus, asserted that the quality of reduction is more important than the method of reduction.

Baumann angle was described as a radiographic measurement to evaluate the reduction in SCHF [12]. Additionally, fragments rotation was the first to appear in case of a loss of reduction and progress to cubitus varus deformity [10, 11]. Gordon et al. and Griffet et al. devised radiographic indexes as a sensitive method to anticipate rotational instability [10, 11]. The authors advocated that anatomic reduction should be achieved to avoid a residual deformity [11]. We confirmed that the Baumann angle and the humerocapitella angle after operative reduction in the SCHF were within a normal reference range in both surgeon groups. The three measured indexes were also comparable. The proportion of children who achieved an acceptable range of Baumann angle was similar for both groups of surgeons [12, 13].

An overall complication rate in this cohort was comparable to previous reports from other centers despite having children who were managed by orthopedic surgeons with a variety of subspecialty training background [1]. Several

factors such as poor surgical technique, SCHF with Gartland type 3, higher BMI than 25 kg/m^2 and medial cortex comminution may contribute to the loss of implant fixation after surgical treatment of pediatric SCHF [21, 22]. Gartland type 3 with medial comminution represented the most severe SCHF type, and an extra precaution should be exercised. A K-wire configuration could be a contributing factor. The use of cross K-wire configuration was recommended to give a stronger fixation pattern biomechanically [21] albeit an increased risk of ulna nerve injury from the medial K-wire; thus, the lateral-entry technique with 3 K-wires was later endorsed [23, 24]. The meticulous surgical technique for K-wire placement is the utmost importance, and it should be strictly followed. Testing the stability after fixation is crucial [10]. The threshold of adding a medial or a third lateral K-wire cannot be overemphasized [10, 22, 24].

Iatrogenic nerve injury associated with instrumentation in SCHF occurred infrequently [23, 25]. The ulna nerve was at a greater risk with a medial K-wire [23, 26, 27], while the radial and median nerves could be at risk from a lateral K-wire [23, 26, 28]. Most of the iatrogenic nerve injury was neurapraxia, and expectant treatment yielded a satisfactory result [26–28]. To the best of our knowledge, there was no report of radial nerve laceration from a lateral-entry K-wire. We suspected that this could be due to a technical error. Upon review of the surgical findings and radiographs, the lateral-most K-wire exited at the anterolateral cortex of the distal humerus and pierced through the radial nerve. Skaggs et al. [24] emphasized the technique of insertion of lateral-entry K-wire that one K-wire should be straight up the lateral column and engage the opposite cortex of the proximal fragment. In this situation, the nerve should be explored and repaired.

Wound infection rarely occurs, regardless whether an open or close reduction is done [13, 24]. The infection usually is confined to the superficial part and is easily eradicated by local dressing and oral antibiotics. Delayed open reduction in SCHF Gartland type 3 may increase the risk of developing infection of the wound [18]. Nonetheless, a spreading of local infection into an elbow joint could develop. We encountered one case that required an open debridement. When the elbow started to swell and the swelling of the soft tissue did not subside within the proper time frame, the physicians should suspect that it is due to septic arthritis.

A few limitations need to be mentioned. Due to a nature of a retrospective review, clinically perceivable cubitus varus, limited elbow range of motion or a functional score was not available. However, if the Baumann angle and the anterior humeral line were restored, the children should attain good functional outcomes [29]. The long-term complication related to an open reduction procedure (i.e., unattractive scar or heterotrophic ossification) was not recorded.

In summary, radiographic outcomes and complications of surgically treated pediatric SCHF did not differ among orthopedic surgeons with different backgrounds of their subspecialty training. These data support the treatment of pediatric SCHF without open wound or vascular impairment could be efficiently managed by a general orthopedic surgeon. SCHF with Gartland type 3 required a special precaution. Complications could be catastrophic if unrecognized and should be promptly managed.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. For this type of study, formal consent is not required.

References

1. Kasser JR (2005) Location of treatment of supracondylar fractures of the humerus in children. Clin Orthop Relat Res 434:110–113. https://doi.org/10.1097/01.blo.0000162410.47731.69
2. Farley FA, Patel P, Craig CL, Blakemore LC, Hensinger RN, Zhang L, Caird MS (2008) Pediatric supracondylar humerus fractures: treatment by type of orthopedic surgeon. J Child Orthop 2(2):91–95. https://doi.org/10.1007/s11832-008-0089-x
3. Lee S, Park MS, Chung CY, Kwon DG, Sung KH, Kim TW, Choi IH, Cho TJ, Yoo WJ, Lee KM (2012) Consensus and different perspectives on treatment of supracondylar fractures of the humerus in children. Clin Orthop Surg 4(1):91–97. https://doi.org/10.4055/cios.2012.4.1.91
4. Pullagura M, Odak S, Pratt R (2013) Managing supracondylar fractures of the distal humerus in children in a district general hospital. Ann R Coll Surg Engl 95(8):582–585. https://doi.org/10.1308/003588413x13629960047074
5. Zirkle LG Jr (2008) Injuries in developing countries–how can we help? The role of orthopaedic surgeons. Clin Orthop Relat Res 466(10):2443–2450. https://doi.org/10.1007/s11999-008-0387-0
6. Yildirim AO, Unal VS, Oken OF, Gulcek M, Ozsular M, Ucaner A (2009) Timing of surgical treatment for type III supracondylar humerus fractures in pediatric patients. J Child Orthop 3(4):265–269. https://doi.org/10.1007/s11832-009-0189-2
7. Sabatini CS, Skaggs KF, Kay RM, Skaggs DL (2012) Orthopedic surgeons are less likely to see children now for fracture care compared with 10 years ago. J Pediatr 160(3):505–507. https://doi.org/10.1016/j.jpeds.2011.08.020
8. Abbott MD, Buchler L, Loder RT, Caltoum CB (2014) Gartland type III supracondylar humerus fractures: outcome and complications as related to operative timing and pin configuration. J Child Orthop 8(6):473–477. https://doi.org/10.1007/s11832-014-0624-x
9. Iyengar SR, Hoffinger SA, Townsend DR (1999) Early versus delayed reduction and pinning of type III displaced supracondylar fractures of the humerus in children: a comparative study. J

Orthop Trauma 13(1):51–55. https://doi.org/10.1097/00005131-199901000-00012
10. Gordon JE, Patton CM, Luhmann SJ, Bassett GS, Schoenecker PL (2001) Fracture stability after pinning of displaced supracondylar distal humerus fractures in children. J Pediatr Orthop 21(3):313–318. https://doi.org/10.1097/01241398-200105000-00010
11. Griffet J, Abou-Daher A, Breaud J, el Hayek T, Rubio A, el Meouchy W (2004) Systematic percutaneous pinning of displaced extension-type supra-condylar fractures for the humerus in children: a prospective study of 67 patients. Eur J Orthop Surg Traumatol 14(4):214–220. https://doi.org/10.1007/s00590-004-0170-1
12. Worlock P (1986) Supracondylar fractures of the humerus. Assessment of cubitus varus by the Baumann angle. J Bone Joint Surg Br 68(5):755–757
13. Lewine E, Kim JM, Miller PE, Waters PM, Mahan ST, Snyder B, Hedequist D, Bae DS (2016) Closed versus open supracondylar fractures of the humerus in children: a comparison of clinical and radiographic presentation and results. J Pediatr Orthop. https://doi.org/10.1097/bpo.0000000000000769
14. American Academy of Orthopaedic Surgeons (2017) Guide to orthopaedic practices and subspecialties. https://www.aaos.org/uploadedFiles/PreProduction/Membership/Career_Development/Medical_Student_Resources/Guide_to_orthopaedic_practices.pdf. Accessed 8 Aug 2017
15. United Nations (2016) World economic situation and prospects 2016. http://www.un.org/en/development/desa/policy/wesp/wesp_current/2016wesp_full_en.pdf. Accessed 25 Aug 2017
16. Lucas Murnaghan M, Slobogean BL, Byrne A, Tredwell SJ, Mulpuri K (2010) The effect of surgical timing on operative duration and quality of reduction in Type III supracondylar humeral fractures in children. J Child Orthop 4(2):153–158. https://doi.org/10.1007/s11832-010-0240-3
17. Garg S, Weller A, Larson AN, Fletcher ND, Kwon M, Schiller J, Browne R, Copley L, Ho C (2014) Clinical characteristics of severe supracondylar humerus fractures in children. J Pediatr Orthop 34(1):34–39. https://doi.org/10.1097/bpo.0b013e31829c0046
18. Aslan A, Konya MN, Ozdemir A, Yorgancigil H, Maralcan G, Uysal E (2014) Open reduction and pinning for the treatment of Gartland extension type III supracondylar humeral fractures in children. Strat Trauma Limb Reconstr 9(2):79–88. https://doi.org/10.1007/s11751-014-0198-7
19. Guven MF, Kaynak G, Inan M, Caliskan G, Unlu HB, Kesmezacar H (2015) Results of displaced supracondylar humerus fractures treated with open reduction and internal fixation after a mean 22.4 years of follow-up. J Shoulder Elbow Surg 24(4):640–646. https://doi.org/10.1016/j.jse.2014.12.010
20. Simanovsky N, Lamdan R, Mosheiff R, Simanovsky N (2007) Underreduced supracondylar fracture of the humerus in children: clinical significance at skeletal maturity. J Pediatr Orthop 27(7):733–738. https://doi.org/10.1097/bpo.0b013e3181558a63
21. Sangkomkamhang T, Singjam U, Leeprakobboon D (2014) Risk factors for loss of fixation in pediatric supracondylar humeral fractures. J Med Assoc Thai 97(Suppl 9):S23–S28
22. Reisoglu A, Kazimoglu C, Hanay E, Agus H (2017) Is pin configuration the only factor causing loss of reduction in the management of pediatric type III supracondylar fractures? Acta Orthop Traumatol Turc 51(1):34–38. https://doi.org/10.1016/j.aott.2016.11.003
23. Woratanarat P, Angsanuntsukh C, Rattanasiri S, Attia J, Woratanarat T, Thakkinstian A (2012) Meta-analysis of pinning in supracondylar fracture of the humerus in children. J Orthop Trauma 26(1):48–53. https://doi.org/10.1097/bot.0b013e3182143de0
24. Skaggs DL, Cluck MW, Mostofi A, Flynn JM, Kay RM (2004) Lateral-entry pin fixation in the management of supracondylar fractures in children. J Bone Joint Surg Am 86-A(4):702–707. https://doi.org/10.2106/00004623-200404000-00006
25. Reitman RD, Waters P, Millis M (2001) Open reduction and internal fixation for supracondylar humerus fractures in children. J Pediatr Orthop 21(2):157–161. https://doi.org/10.1097/01241398-200103000-00004
26. Babal JC, Mehlman CT, Klein G (2010) Nerve injuries associated with pediatric supracondylar humeral fractures: a meta-analysis. J Pediatr Orthop 30(3):253–263. https://doi.org/10.1097/bpo.0b013e3181d213a6
27. Sinikumpu JJ, Victorzon S, Lindholm EL, Peljo T, Serlo W (2014) Ulnar nerve morbidity as a long-term complication of pediatric supracondylar humeral fracture. Musculoskelet Surg 98(2):127–133. https://doi.org/10.1007/s12306-013-0291-y
28. Brown IC, Zinar DM (1995) Traumatic and iatrogenic neurological complications after supracondylar humerus fractures in children. J Pediatr Orthop 15(4):440–443. https://doi.org/10.1097/01241398-199507000-00005
29. Tuomilehto N, Kivisaari R, Sommarhem A, Nietosvaara AY (2017) Outcome after pin fixation of supracondylar humerus fractures in children: postoperative radiographic examinations are unnecessary. Acta Orthop 88(1):109–115. https://doi.org/10.1080/17453674.2016.1250058