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ORIGINAL RESEARCH

# Open Reduction and Fixation of Late-Presenting Pediatric Supracondylar Humeral Fractures: A Prospective Study

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**Background:** Supracondylar humeral fracture (SCHF) is a common injury in children, and early treatment provides excellent results and prevents disabilities. Delayed presentation is still prevalent, mainly in developing countries, because many factors hinder the opportunity to receive appropriate treatment. Currently, there are no standard treatment protocols, and there is insufficient published literature on this topic. This study aimed to evaluate the effectiveness and outcomes of open reduction and Kirschner wire fixation using a triceps-sparing posterior approach in neglected cases with complicated fractures.

**Methods:** This was a prospective multicenter clinical study conducted between July 2016 and June 2021, which included 28 pediatric patients with neglected SCHF who presented to the hospital for definitive treatment five days or more after initial trauma without previous surgical intervention. All the patients underwent open reduction and K-wire fixation using a posterior triceps-sparing approach. The final functional outcome was assessed using the Mayo Elbow Performance Index (MEPI) and Flynn criteria.

**Results:** All fractures (100%) united within 3–5.5 weeks (mean 4 ± 0.7 weeks). Excellent scores observed in 67.9% (n = 19), good in 21.4% (n = 6), fair in 7.1% (n=2), and poor in 3.6% (n = 1) patients according to MEPI. Correspondingly, Flynn's criteria showed 96.4% (n = 27) satisfactory and 3.6% (n = 1) unsatisfactory outcome.

**Conclusion:** Open reduction and fixation using Kirschner wires through the posterior triceps-sparing approach is an effective treatment method for late-presenting SCHF in children with consequent satisfactory results.

**Keywords:** children, neglected, triceps-sparing, posterior approach, Kirschner wires

## Introduction

Supracondylar humeral fracture is a common fracture in the pediatric population, it accounts approximately 55–5% of all fractures around the elbow and approximately 15% of all fractures in this age group.[1,2] This fracture occurs in children usually between 5 and 10 years due to a fall on the outstretched hand (FOOSH), which is the most often type of injury (95–98%) with axial transmission of body weight through the maximally extended elbow, but it can also result from other less common mechanisms.[3] In the majority 97–99%, the distal fragment displaces posteriorly, this is known as extension type fracture. Flexion-type injuries are less common, accounting for approximately 1–3%, in which the distal part displaces anteriorly.[4] Open fractures are very rare, occurring mainly in older children and accounting for 1% or less.[2]

Non-displaced fractures are routinely treated with a short period of immobilization and an active range of movement (ROM) after union. Closed reduction and percutaneous pinning (CRPP) is the gold-standard treatment for most displaced fractures. Open reduction can be performed in irreducible and difficult cases, late presentations, or in those associated with vascular injury. Less frequently, in cases of massive swelling, skin or skeletal traction is applied until the condition improves; however, external fixation is rarely used in pediatrics.[5,6]

In developing countries, 10–20% of cases present late for treatment. This delay is due to many factors including poor healthcare system, lack of health education, traditional beliefs and interventions by non-medical personnel, inadequate treatment, ignorance, financial problems, long-distance referrals and difficult transportation.[1,7–9] Generally, there is no

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widely accepted time delay for late presentation, and in the literature, the minimum delay time is 2 days from injury and the maximum is 14 days or more without definitive treatment (range 2–14 days), but objectively it is when callus appear in plain radiography, while the fracture line is still visible, which is usually evident by the end of the first week (5–7 days) after which closed reduction is practically difficult due to swelling, poor skin condition, contracted soft tissues and the presence of soft callus.[1,6–8,10,11] Currently, there is no general consensus regarding treatment protocols for neglected SCHF in children, so, it is still controversial whether to perform continuous traction which requires prolonged hospitalization, to allow it to malunite and to perform later corrective osteotomy, to conduct a closed calloclasis and reduction, or to perform an open reduction and fixation after removal of callus at presentation.[6,12]

The high prevalence of neglected fractures in our environment, along with the lack of reports and guidelines, motivated this study. Our goals were to share our experiences and contribute to the literature on this topic.

## Materials and Methods

This prospective multicenter clinical study was conducted between July 2016 and June 2021 in the orthopaedic departments of three teaching hospitals in Gezira State, Sudan. The hospitals were Almanagil Teaching Hospital, Rofaa Teaching Hospital, and Gezira Center of Trauma and Orthopaedic Surgery. A total of 28 patients (19 boys and 9 girls) were included in this study, their ages between 3 and 12 years (mean: 7.54 ± 2.3 years). All were pediatric patients with neglected SCHF who were presented to the hospital for definitive treatment five days or more after the initial trauma without previous surgical intervention.

The mean time for delay at presentation was 13.57 ± 7.4 days (range 5–30 days). Reasons for delay included inadequate treatment 17.9% (n = 5) by medical personnel in remote medical centers or peripheral hospitals with unavailable medical equipment or skilled physicians, difficult transportation to the nearest secondary hospital from a distant rural area 10.7% (n = 3) due to rough roads or unavailable transportation, financial or medical insurance problems 7.1% (n = 2), which hamper adequate medical care processes in developing countries, and the majority were due to traditional treatment and beliefs 64.3% (n = 18), this is mainly because most of patients were residents of rural regions 82.1% (n = 23), in which traditional treatment by bone setters or other non-medical healers is still prevalent. All of these factors restrained early presentation to fully equipped hospitals. On the other hand, only 17.9% (n = 5) of patients were from an urban city.

The mechanism of injury in all patients was FOOSH. Detailed clinical evaluation of all patients was carefully conducted, including a full history, thorough examination, and radiological studies. All of them had calluses but a visible fracture line on their X-rays. In 60.7% (n = 17), the fracture was on the left side and in 39.3% (n = 11) was on the right upper extremity, none had bilateral fractures. Regarding skin and soft tissue conditions, 14.3% (n = 4) had scars, 7.1% (n = 2) had crusts, 7.1% (n = 2) had infected lacerations, 3.6% (n = 1) had clean abrasions, 3.6% (n = 1) had blisters, 3.6% (n = 1) had moderate swelling, but the majority 60.7% (n = 17) had good skin and soft tissue conditions. None of the patients had peripheral neurovascular compromise, compartment syndrome, or Volkmann ischemic contractures. Case examples are shown in Figure 1 along with their clinical and radiological features at presentation.

Fractures were classified according to Gartland's classification[13] with the most recent modifications,[14,15] as shown in Table 1. Most patients 89.3% (n = 25) had an isolated SCHF fracture without other injuries: one male (5 years) 3.6% had ipsilateral upper limb fracture (Salter-Harris distal radius epiphyseal injury), one female (8 years) 3.6% had cut wound on the scalp, and one male (6 years) 3.6% had contralateral tibial shaft fracture. Twenty-six (92.9%) had neither history of comorbidities nor were on chronic medications, only 2 (7.1%) were asthmatic with salbutamol. No other systemic medical problems or allergies have been reported. Patients with associated distal radial epiphysis and tibial shaft fractures were treated in the same operative session with open reduction and fixation using wires and elastic nails, respectively. The scalp-cut wound was sutured at presentation, and no further intervention was required.

The time from injury to operation (operation delay) was between 7 and 31 days (mean 15.68 ± 7.3 days), which is different from the presentation delay time above. In the majority of patients, preparations required 0–3 days; however, in 6 patients, some problems had to be resolved before surgery. Two male (5 and 7 years) patients presented with infected lacerations who received a short course of antibiotics and dressing for 4–5 days, one female (12 years old) presented with blisters due to tight traditional splints that had been delayed for 9 days until the blisters healed completely, and two male

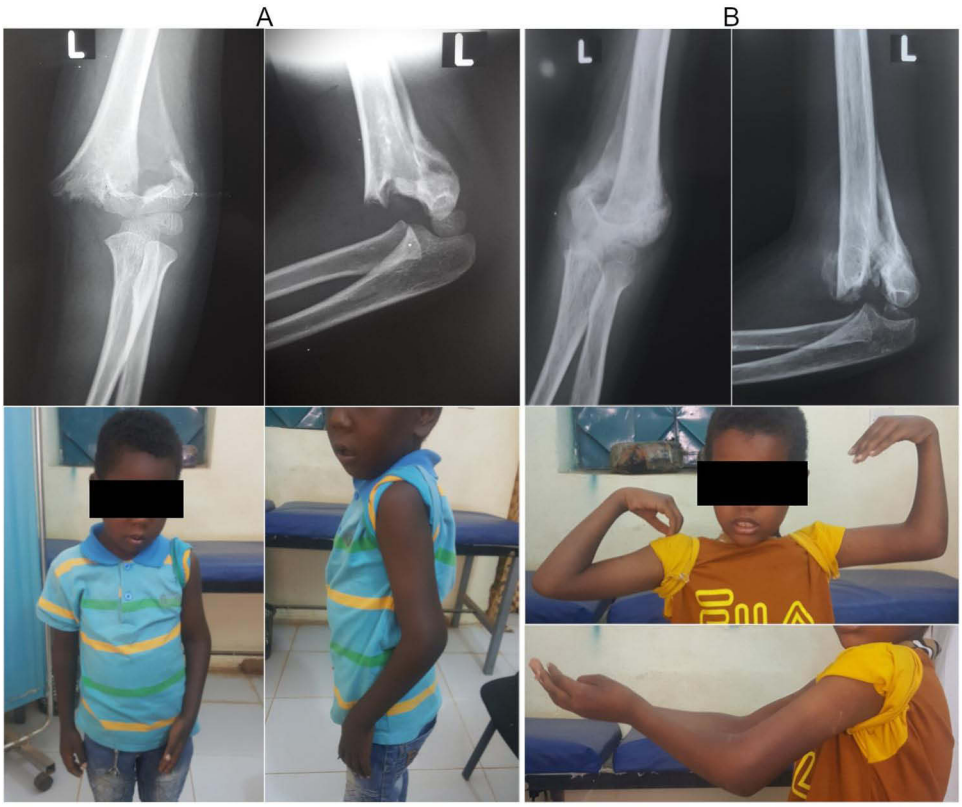


**Figure 1** Case examples at presentation: Radiological and clinical images of 4 years old male presented 16 days after trauma (**A**), 7 years old male presented 29 days post-trauma, with severe elbow stiffness (**B**).

and female candidates (5 and 8 years, respectively) had financial and insurance issues solved within 5 days. Finally, one male (8 years) had moderate elbow swelling treated by Dunlop traction for 3 days until the swelling subsided.

## Surgical Procedure

The surgical procedure was performed under general anesthesia in the lateral decubitus position with the affected upper limb hanging over a side post and application of pneumatic tourniquet at the proximal end of the extremity (pressure was set at 50 mmHg more than the patient's systolic pressure).[16] The posterior triceps-sparing approach described by Alonso-Llames[17] was used for surgical exposure. The approach was performed with an 8–15 cm skin incision with dissection of the subcutaneous tissue, two-thirds of the incision proximal to the elbow, and one-third distal. The ulnar nerve was explored, preserved, and gently mobilized without excessive traction, whereas the radial nerve was identified and protected during the surgery. The triceps muscle was dissected medially and laterally off the intermuscular septum and

**Table 1** Frequency of Fractures Types According to Gartland's Classification

| Classification | Number of Patients | Percent |
|---|---|---|
| Type II (Displaced in 1 plane) | 7 | 25% |
| Type III (Displaced in 2 or 3 planes) | 9 | 32.1% |
| Type IV (complete periosteal disruption and instability) | 7 | 25% |
| Medial comminution | 3 | 10.7% |
| Flexion type | 2 | 7.1% |

**Notes**: Data from these studies.[13–15].

elevated from the posterior humerus while preserving its attachment to the olecranon. All obvious calluses were removed using the medial and lateral windows provided by the approach until the fracture site was exposed. Open reduction and fixation were performed under direct vision and confirmed with intraoperative X-ray imaging using a C-arm machine. The reduced fragments are fixed with two 78.6% (n = 22) or three 21.4% (n = 6) medial and lateral 1.5–2 mm crossed Kirschner wires according to fracture stability. In all patients, the K-wires protruded from the skin for easy removal in the outpatient clinic. These steps are illustrated in Figure 2.

The tourniquet deflated, and adequate hemostasis was achieved, after which the wound was closed in layers with loose approximation of the lateral and medial muscle windows. The ulnar nerve returned to its groove behind the medial epicondyle, ensuring no contact or pressure from the medial K-wire. The skin and subcutaneous tissue were closed without tension, and no drain was used. The elbow back slab was applied to the upper limb at 90° flexion. The mean operation time was 54.29 ± 20.6 minutes (range 20–90 min), which was calculated from the induction of anesthesia until initial recovery. Post-operative care was initiated immediately after surgery, with full clinical and radiological assessments. Figure 3 shows two fractures with different numbers of Kirschner wires.

Postoperative hospital stay ranged between 12 and 48 hours (mean 27.43 ± 11.7 hours). On the other hand, the total hospital stay from admission until discharge differed, mean of 3.14 ± 2.3 days (range 0.5–11 days), because some patients had problems that necessitated clearance before the operation, as previously mentioned. After discharge, all patients were followed up for two weeks, and the slab and sutures were removed with active ROM started as tolerated with the K-wires in place. Regular visits continued every week until the complete union and removal of wires, then monthly for the first 6 months, then every 3 months until the last visit at which functional outcome was calculated using Mayo Elbow Performance Index (MEPI) and Flynn's Criteria.[11,18] Mean follow-up period was 9.32 ± 5.1 months (range

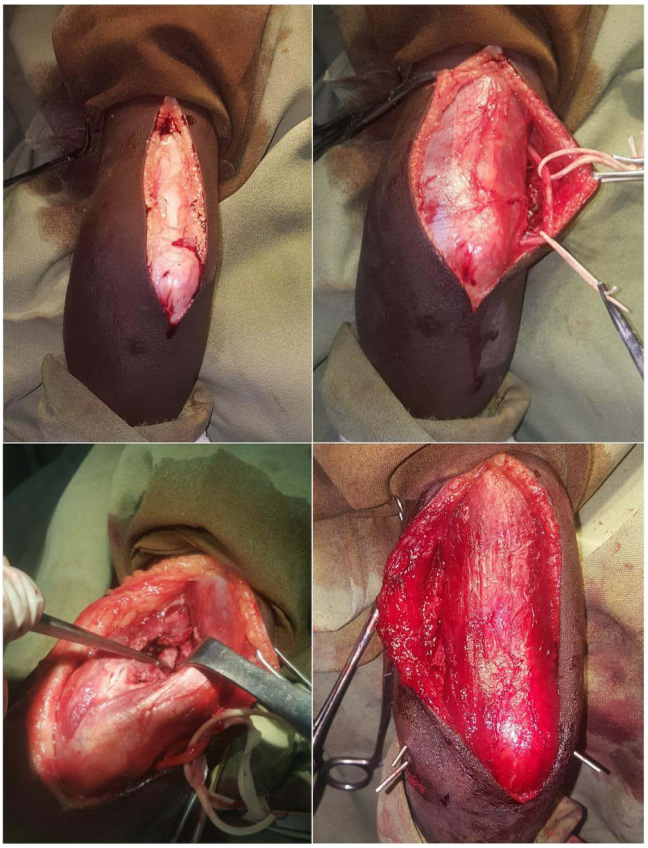

**Figure 2** Triceps-sparing approach: Skin incision (top left), exploration of ulnar nerve (top right), removal of callus (bottom left), reduction and K-wires fixation (bottom right).

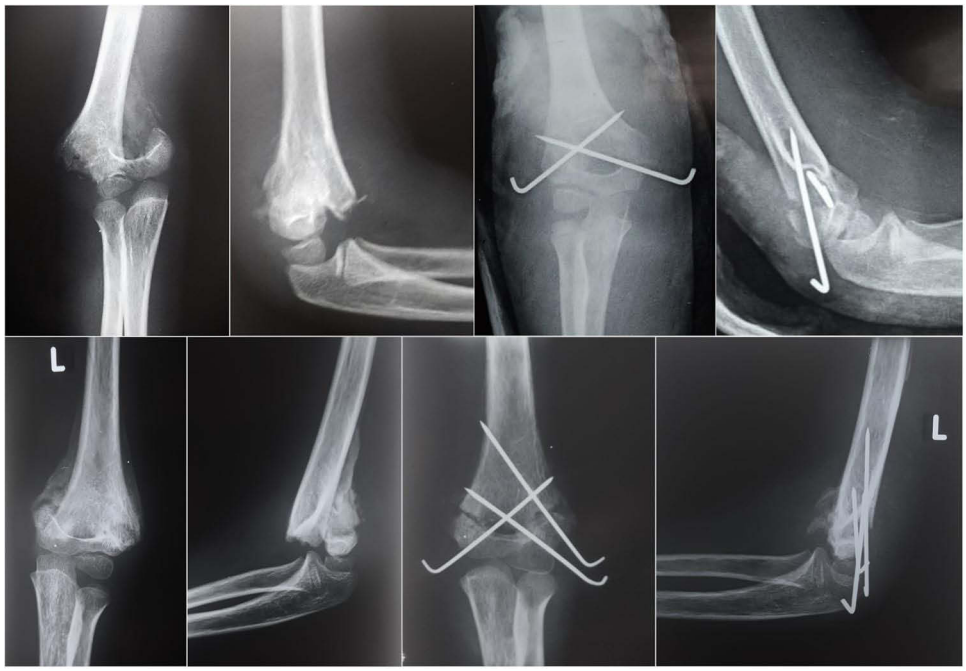


**Figure 3** Fixation with different number of K-wires: (Top) type III, 2 weeks neglected SCHF fixed with two K-wires. (Bottom) type IV, 4 weeks delayed presentation fixed with 3 K-wires.

6–24 months). Continuous evaluation, monitoring, and recording of outcomes and complications were performed throughout the follow-up period, from the operation to the last visit.

## Data Collection and Statistical Analysis

Data were collected by the corresponding author using structured questionnaires from direct observations, clinical and radiological evaluations, medical files, and follow-up cards, which included sociodemographic data, medical history, physical examination, fracture classification, operation details, follow-up information, and functional outcome scores.

Statistical analyses were performed using IBM SPSS version 26 software. Mean, standard deviation, frequency, and percentage were calculated. The chi-square test was used for bi-variant results when applicable.

# Results

All fractures (100%) showed clinical and radiological union, and the mean time was 4 ± 0.7 weeks (range 3–5.5 weeks). None of the patients had nonunion or delayed union.

All patients (100%) had some degree of elbow stiffness, and all of them underwent physiotherapy sessions after removal of wires for 1–12 months (mean 2.71 ± 2.7 months). We adapted the Mansat and Morrey classification[19] for elbow stiffness, which has been accepted by many authors.[20–23] The measures were taken using a goniometer after the

**Table 2** Occurrence of Elbow Stiffness According to Mansat and Morrey classification

| Grade | Number of Patients | Percentage |
|---|---|---|
| Mild (> 90°) | 19 | 67.9% |
| Moderate (60–90°) | 7 | 25% |
| Severe (30–60°) | 2 | 7.1% |
| Extremely severe (< 30°) | 0 | 0% |

**Notes:** Data from Mansat and Morrey.[19]

**Table 3** Functional Results According to Mayo Elbow Performance Index (MEPI)

| Score | Frequency |
|---|---|
| Excellent 90–100 | 19 (67.9%) |
| Good 75–89 | 6 (21.4%) |
| Fair 60–74 | 2 (7.1%) |
| Poor 0–59 | 1 (3.6%) |

**Notes:** Data from Morrey and Adams.[18]

**Table 4** Functional Outcome According to Flynn's criteria

| Result | Frequency | Rating | Loss of Carrying Angle | Loss of Motion | Frequency |
|---|---|---|---|---|---|
| Satisfactory | 27 (96.4%) | Excellent | 0°-5° | 0°-5° | 18 (64.3%) |
| | | Good | 5°-10° | 5°-10° | 6 (21.4%) |
| | | Fair | 10°-15° | 10°-15° | 3 (10.7%) |
| Unsatisfactory | 1 (3.6%) | Poor | >15° | >15° | 1 (3.6%) |

**Notes:** Data from Flynn et al.[11]

removal of the K-wires. Table 2 presents the results. All patients improved and recovered a useful ROM, except for one patient with severe stiffness complicated by myositis ossificans requiring manipulation under anesthesia (MUA).

For other complications, two patients 7.1% male and female (10 and 8 years, respectively) had pin tract infection, treated with 2 weeks course of antibiotics, local debridement and daily dressing, a swab from the site of infection sent for culture and sensitivity, therewith treatment adjusted accordingly, while the wires were retained until full union. Both patients responded well to the treatment, and the infection resolved without any consequences. One 3.6% male (7 years) with Type IV fracture had pin loosening; the wire was one of two lateral wires, removed after 2 weeks with the wound sutures without further deterioration in his condition. The fracture reduction was stable because it was fixed with three crossed K-wires: one medial and two lateral. Another one 3.6% male (8 years) developed myositis ossificans with severe elbow stiffness, a special form of physiotherapy session adjusted to his condition performed for 6 months until the end of maturation phase. Subsequently, the patient underwent MUA, followed by regular physiotherapy for another 6 months. To date, there is no consensus on the use of nonsteroidal anti-inflammatory drugs (NSAIDs) as prophylaxis against heterotopic ossification (HO) in the pediatric population,[24] therefore, indomethacin or other NSAIDs are not administered for such purposes. The patient and his family were non-compliant with treatment; the parents refused to undergo another surgery for HO excision, and he had a poor outcome. In the remaining 85.7% (n = 24), no further complications were reported other than elbow stiffness. None of the patients had iatrogenic nerve palsy, vascular damage, compartment syndrome, chronic osteomyelitis or cubitus varus.

Regarding functional outcomes, as shown in Tables 3 and 4, twenty-seven (96.4%) cases had satisfactory, but only one (3.6%) reported unsatisfactory outcomes. The results of the Mayo Elbow Performance Index (MEPI) and the Flynn criteria were similar. Figures 4 and 5 show the follow-up and outcome of the two sample cases.

## Discussion

Delayed presentation of SCHF in children is still common, especially in the third world, due to problems in healthcare system organization, low socioeconomic status, poor medical insurance processes, limited infrastructure, difficult transportation, and prevalent incorrect traditional beliefs and interventions by non-medical personnel.[7–9] In general, the treatment of neglected cases with late presentation remains controversial, despite the fact that there are some widely

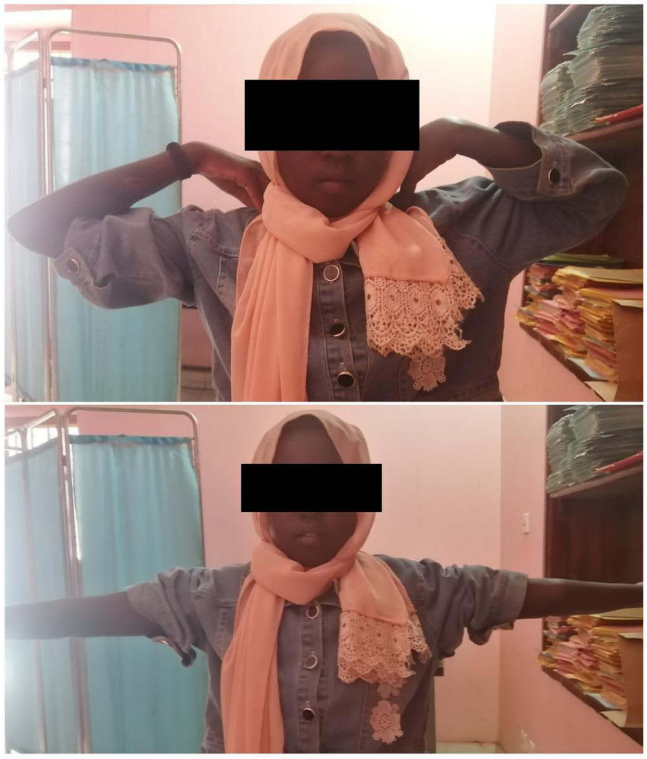

**Figure 4** Outcome in 8 years old girl: ROM at final follow-up visit 6 months post-operative. The patient presented with neglected right side SCHF 16 days after receiving traditional treatment by bone setter. Treated by open reduction and K-wire fixation.

used methods of treatment, including prolonged traction with inevitable lengthy hospitalization, closed calloclasis, open reduction and fixation or late corrective osteotomy after malunion. Open reduction for neglected SCHF has gained popularity in recent years because of its lower rate of complications and better outcome.[6–10]

A review of the literature has revealed that different methods have been used for the treatment of late-presenting SCHF. Devnani[8] performed gradual skin traction, while Ağuş et al[25] conducted skeletal traction and delayed percutaneous fixation, and they, respectively, reported 25% and 15.3% cubitus varus that required later corrective osteotomy, along with the long hospital stay required for these old methods of treatment. Hussain et al[5] and Samal et al[1] used calloclasis and closed reduction with percutaneous K-wire fixation, 71.7% of patients in the first and 88.9–90.3% in the second had excellent results, but both studies reported occurrence of cubitus varus and Iatrogenic ulnar nerve injury, and some cases converted to open reduction after failure of closed calloclasis. Maharjana and Kawiyana in their work[3] executed different types of reconstructive procedures and corrective osteotomies; they had 25–37.5% excellent, 50–75% good, and 12.5% fair outcomes.

According to our research, many authors prefer open reduction, callus removal, and K-wire fixation, with different approaches reported for the exposure of the fracture site. Eren et al[26] utilized the medial approach, but Guo et al,[27] in their retrospective review, employed an anterior approach. In a case series by Yi et al[28] they described the application of lateral and posterior approaches. There are many versions of the posterior approach with regard to triceps dissection; Lal and Bhan[29] used the V-Y triceps-plasty variety, Sumarwoto et al[10] and Shah et al[7] achieved open reduction through triceps split, while Tiwari et al[6] and Rizk[9] reported that the triceps-sparing posterior approach was selected. Most manifested better outcomes and early recovery compared to other treatment methods, with no or very limited late sequelae. In our study, the triceps-sparing posterior approach was favored because of its many advantages, including good exposure, excellent visualization of the fracture site, preservation of the extensor mechanism, avoidance of ulnar and radial nerve injuries, and a low incidence of postoperative stiffness.[6,9,17]

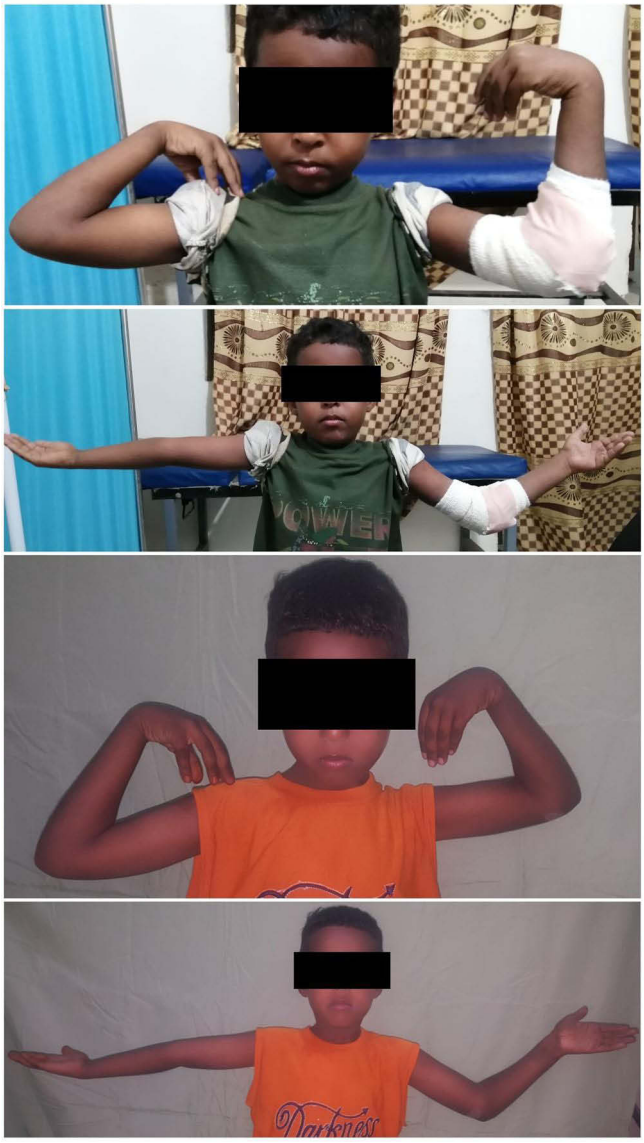

**Figure 5** Follow-up and outcome in 7 years old boy with left side neglected SCHF and 30 days of delay. ROM immediately after removal of K-wires and 2 months postoperatively. The patient elbow flexion was excellent but extension required 5 months of physiotherapy to improve.

Remarkably, K-wires are the most used tools for fixation of neglected SCHF in children by the majority of surgeons; however, Fu et al[30] obtained fixation with bioabsorbable pins and Sumarwoto et al[10] fulfilled the purpose with a combination of K-wires and cortical screws. Both the studies reported similar outcomes.

Post-operative hospital stay in this study was 12–48 hours (mean 27.43 hours), but for the total hospital stay, it was 0.5–11 days (mean 3.14 days). This is because some patients had conditions that were contradictory to prompt surgery. Eren et al[26] average hospital stay of 2 days (range 1–3 days), whereas Hussain et al reported a mean hospital stay of 3.6 days (1–9 days) in Hussain et al[5] research. In contrast, Devnani[8] reported a mean stay of 14 days (range, 7–22 days); however, this is related to the traction method used, which necessitates prolonged admission.

With respect to union, we obtained 100% result at 3–5.5 weeks (mean 4 ± 0.7 weeks). Rizk[9] had a mean duration of 7.2 weeks (range 5–10 weeks), whereas Maharjana and Kawiyana[3] reported a mean of 14.42 weeks. This difference is possibly due to the older age and longer delay time in their studies, but generally, nonunion and delayed union are rarely encountered in the pediatric population.

In the current study, all patients required post-operative physiotherapy for elbow stiffness for 1–12 months (mean 2.7 months). This is justified by the fact that late presentation is usually associated with some degree of stiffness due to swelling, soft tissue contraction and callus, along with the surgical intervention and scarring that may add further tissue compromise, but the motion in pediatric almost nearly recovers with physiotherapy after healing.[7] The bulk of our cases regained a useful range of movement finally, and only one patient (3.6%) had unacceptable endeavor due to non-compliance with treatment. Hussain et al[5] reported that 6.5% of patients had deficient ROM at 1-year follow-up. This result is not far from those achieved in other studies.[1,7,26,30]

Other complications occurred in four children: two (7.1%) had pin tract infection, one (3.6%) had pin loosening, and one developed myositis ossificans. Three patients improved and showed subsequent satisfactory outcomes, and only one patient had a poor outcome. Samal et al[1] reported five cases of pin tract infection and three cases of iatrogenic transient ulnar nerve injury in patients treated with closed reduction and pinning. Among those treated with traction in the Devnani study,[8] seven had cubitus varus, two had cubitus rectus, and five had elbow hyperextension deformity. The majority of similar studies[6,7,9,10,26,29,30] on open reduction and fixation reported pin tract infection, pin loosening, re-fracture, and avascular necrosis of the trochlea. However, most patients have no or very low rates of iatrogenic nerve injury or elbow deformity.

The final outcome was measured using MEPI and Flynn criteria. Seventy-two (96.4%) of our cases had satisfactory and only one (3.6%) had unsatisfactory outcome. Excellent scores were observed in 67.9%, good in 21.4%, fair in 7.1%, and poor in 3.6% patients. Comparably, excellent results were found in (86.66%), and good results were found in (13.33%) of patients regarding MEPI score in Rizk report,[9] while Tiwari et al[6] conveyed 42.5% excellent, 30% good, 15%, and 12.5% of endings.

This study has some limitations, including a small sample size, lack of randomization, no control group, and a short follow-up period. However, it has several strengths because it is prospective and multicentric. To date, there are no standard protocols for the management of neglected or late-presenting SCHF in children, and there remains a lack of literature on this topic. We aimed to contribute to treatment guidelines with these promising results.

## Conclusion

Open reduction and K-wire fixation have proven to be successful treatment methods with satisfactory outcomes and minimal complications for neglected or late-presenting SCHF in children. The triceps-sparing approach provides good exposure, excellent visualization, and preservation of the extensor mechanism. It is simple, safe, and has a low incidence of postoperative stiffness.

## Abbreviations

AO, Arbeitsgemeinschaft für Osteosynthesefragen (Association of the Study of Internal Fixation); CRPP, Closed Reduction and Percutaneous Pinning; FOOSH, Fall On Outstretched Hand; HO, Heterotopic Ossification; MEPI, Mayo Elbow Performance Index; MUA, Manipulation Under Anesthesia; NSAIDs, Non-Steroidal Anti-Inflammatory Drugs; ROM, Range of Movement; SCHF, Supracondylar Humeral Fracture.

## Ethics Approval and Informed Consent

The study was approved by the Ethical and Research Committee of the Ministry of Health-Gezira State and Institutional Review Boards of all hospitals where the study was conducted, and was performed in accordance with the Helsinki Declaration of 1975 and its later amendments. Informed consent obtained from the parents/guardians of all patients before enrollment in this study. They also provided their written permission to publish the images taken of their children.

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## Disclosure

The author reports no conflicts of interest in this work.

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