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Ultrasound-guided Percutaneous Medial Pinning of Pediatric Supracondylar Humeral Fractures to Avoid Ulnar Nerve Injury

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Abstract

Although prevalence is highest in children within the first decade of life, supracondylar humerus fractures can also transpire in individuals older than ten years. The aim of this work was to assess the safety and efficacy of medial pinning in children with supracondylar humerus fractures while utilizing ultrasound imaging guidance to protect and visualize the ulnar nerve. This interventional prospective study was carried out on 30 patients aged from 4 to 12 years old, both sexes, with clinical criteria of closed fracture, and acute fracture within one week. All patients were subjected to: Pre-operative evaluation including full detailed history, general examination, local examination of the Limb, and Investigations [Radiological investigations: X-ray elbow (antero-posterior [AP], lateral, internal oblique), and pre-operative laboratory tests], and general anesthesia in supine position. None of the patients involved in the study had malunion, and sensory or motor ulnar nerve injury, one patient had post slab stiffness which improved at 6 months and 2(6.7%) had pin tract infection and managed by wires cleaning with crusts removal, repeated dressing using local antibiotics and oral antibiotic. all of them recovered at the subsequent follow-up. The final outcome was assessed at 3 months postoperative using Flynn's scoring system and the outcome was 22 (73.3%) patients were excellent, 3 (10%) were good, 3 (10%) patients were fair, and 2 (6.7%) patients were bad. Management of supracondylar fractures with crossed pinning provides excellent fracture stability and provides very low risk of post-operative loss of reduction.

Keywords: Ultrasound-guided, Percutaneous Medial Pinning, Pediatric Supracondylar Humeral Fractures, Ulnar Nerve Injury.

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1. Introduction

Fractures of the supracondylar humerus are among the most prevalent elbow injuries in children [1-2]. Although prevalence is highest in children within the first decade of life, supracondylar humerus fractures can also transpire in individuals older than ten years. Due to the thin structure between the coronoid and olecranon fossae and the susceptibility to bending forces when falling on an outstretched hand, the supracondylar region is highly susceptible to fracture [3]. Cubitus varus, which arises from inadequate or absent reduction, is the most prevalent complication. Cubitus varus, which was once considered purely aesthetic, is now linked to chronic pain, ulnar nerve palsy, posterolateral instability, and an increased risk of other fractures [4-5]. Treatment modalities consist of both conservative and operative approaches.

Percutaneous cross-pinning subsequent to closed reduction is the technique most frequently recommended, garnering favorable cosmetic and functional outcomes. As a result, it has evolved into a conventional treatment approach [4]. The incidence of injury to the ulnar nerve during medial pin insertion is a significant concern in percutaneous cross-pinning of supracondylar fractures, with estimates ranging from 1.4 to 20 %. As a consequence, certain authors propose closed reduction techniques involving solely lateral or medial pin fixation subsequent to small incision visualization of the ulnar nerve [6-7]. The aim of this work was to assess the safety and efficacy of medial pinning in children with supracondylar humerus fractures while utilizing ultrasound imaging guidance to protect and visualize the ulnar nerve.

2. Patients and Methods

This interventional prospective study was carried out on 30 patients aged from 4 to 12 years old, both sexes, with clinical criteria of closed fracture, and acute fracture within one week done after approval from the Ethical Committee the ER Department of Orthopedic surgery in Helwan University Hospital after supracondylar humerus fracture complying. Written informed consent was obtained from the patient or their legal guardians. Associated humerus shaft fracture, acute infection, associated neurovascular injury, pathological fractures, old fractures, ages below 4 years and above 12 years, and open fracture were excluded. All patients were undergone: Pre-operative evaluation including full detailed history, general examination, local examination of the Limb, and Investigations [Radiological investigations: X-ray elbow (antero-posterior [AP], lateral, internal oblique), and pre-operative laboratory tests], and general anaesthesia in supine position.

2.1. Intra operative

The surgical procedure was performed in a supine position while the patient was administered an intravenous antibiotic during induction; the dosage of the antibiotic was modified based on the patient's weight. Each individual was placed in a supine position, with the fractured elbow supported by the table at the wide end of the fluoroscopy unit. While dangling over the table edge, the injured limb was upheld using a radiolucent arm board and folded towels for support. Ateroposterior imaging involved aligning the C-arm with the long axis of the operating table; lateral views of the elbow were obtained by rotating the instrument. Following this, a closed reduction was carried out using fluoroscopic guidance. To prevent neurovascular structures from becoming entangled over an anteriorly displaced proximal fragment, traction was initially administered with the elbow flexed at approximately 20 degrees. The principal surgeon held the forearm in both hands, while the assistant administered counter-traction in the axilla. Following this, the varus and valgus angular alignment were adjusted by utilizing the forearm while the elbow was nearly straight. Furthermore, the surgeon realigned the medial and lateral fracture translation by directly manipulating the distal fragment, as confirmed by the image. After a successful reduction, the child's elbow was flexed to the point where the fingers made contact with the shoulder. The reduction was then evaluated using fluoroscopic images captured in axial, lateral, and oblique planes. Three specific points were assessed to ensure a satisfactory reduction: (a) the AHL intersects the capitellum; (b) Baumann's angle is greater than 10 degrees; and (c) oblique views reveal intact medial and lateral columns.

2.2. Pinning technique

The assistant maintained the elbow in the reduced position of hyperflexion to prevent loss of reduction during pinning, once the reduction was deemed satisfactory.

2.3. Lateral wire

Prior to engaging the medial and lateral cortices, we determined the point of insertion by palpating the lateral humeral condyle. Reduction is performed with 1.6 or 1.8mm wire. To optimize osseous purchase in the sagittal plane, the pin was initiated slightly anterior to the fracture plane and angulated 10 to 15 degrees posteriorly. To determine the starting point, the K-wire is positioned against the lateral condyle without penetrating the skin and examined under AP fluoroscopic guidance. Following an examination of the reduction and wire insertion site, two wires are advanced through the skin towards the opposing cortex.

2.4. Medial wire

With the elbow flexed at a 90-degree angle, the ultrasound transducer is positioned such that its longitudinal axis intersects the line connecting the medial epicondyle and the olecranon. Identification will occur of the ulnar nerve situated within the cubital tunnel and the medial epicondyle. By extending the elbow, the ulnar nerve was detachable from the upper portion of the medial epicondyle. Under ultrasound guidance, the tip of a pin was manually positioned atop the medial epicondyle so as to prevent damage to the ulnar nerve. By referring to the lateral pin, the wire's tip was reoriented while remaining in this location. Subsequently, the pin underwent additional drilling using a drill. The accurate insertion of the pin will be confirmed using fluoroscopic means. Once more, the ultrasound will be utilized to ensure that the ulnar nerve is unobstructed throughout its entire trajectory at the elbow joint. Vascular status was subsequently evaluated. In order to impede the wires from penetrating the skin, they were bent and severed with a minimum distance of 1 to 2 cm from the area. To protect the skin, a sterile felt square with a slit cut into it was then wrapped around the wires.

2.5. Post-operative splinting

Above elbow splint was then applied posteriorly in 45 to 70 degrees of elbow flexion keeping in mind that the pins, not the cast, are holding the fracture reduction.

2.6. Follow up

The participants were assessed clinically using Flynn's criteria and radiologically every 2 weeks till union and report of any associated complications that may occur (Table 1). The primary outcome to describe the safety of ultrasound guided medial pinning of Supracondylar humerus fracture in children to protect ulnar nerve. The secondary outcomes were to describe any complications related to medial pin insertion, that may happen in association with Supracondylar humerus fracture in children fixation, and to evaluate practicality and learning curve of U/S guided pinning.

2.7. Statistical analysis

Utilizing SPSS v28, statistical analysis was conducted (IBM Inc., Armonk, NY, USA). As means and standard deviations (SD), quantitative variables were performed. The frequency and percentage of qualitative variables were defined (%).

3. Results

The average age of the children was 6.73 ± 1.74, 17 (56.7 %) of children were males, 13 (43.3 %) were females, 14 (46.7%) was on the right side, and 16 (53.3 %) of fractures was on the left side (Table 2).

None of the patients involved in the study had malunion, and sensory or motor ulnar nerve injury by assessing intraoperatively using ultrasound nor by post operative examination, one patient had k-wire loosening, one patient had post slab stiffness which improved at 6 months and 2 (6.7%) had pin tract infection and managed by wires cleaning with crusts removal, repeated dressing using local antibiotics and oral antibiotic. all of them recovered at the subsequent follow-up (Table 3). The final outcome was assessed at 3 months postoperative using Flynn's scoring system and the outcome was 22(73.3%) patients were excellent, 3 (10%) were good, 3 (10%) patients were fair, and 2 (6.7%) patients were bad (Table 4).

3.1. Case Presentation

3.1.1. Case 1

A male child 9 years old, student, complained of LT elbow pain following FOOSH. Physical examination revealed LT elbow swelling, ecchymosis, deformity and tenderness over the elbow. Neurovascular examination was intact. First aid was done in form of long posterior above elbow splint. Plain radiographs showed SCFH extension type Gartland type II. He underwent operative treatment by closed reduction and internal fixation (CRIF) with 2 lateral diverting pins and one medial pin by K-wires 1.8 mm. Operative fixation duration was 40 min with 25 images of fluoroscopy (Figure 1).

3.1.2. Case 2

A girl child 5 years old, complained of LT elbow pain following FOOSH. Physical examination revealed LT elbow swelling, ecchymosis, deformity and tenderness all over elbow. Neurovascular examination was intact. First aid was done in form of long posterior above elbow splint. Plain radiographs showed SCFH extension type Gartland type III (Figure 2).

4. Discussion

Fractures of the supracondylar humerus are among the most prevalent elbow injuries in children. Although prevalence is highest in children within the first decade of life, supracondylar humerus fractures can also transpire in individuals older than ten years. The susceptibility of the supracondylar region to fracture is attributed to two factors: the thin structure separating the coronoid and olecranon fossae and its vulnerability to bending forces when an outstretched hand is applied. Cubitus varus, which arises from inadequate or absent reduction, is the most prevalent complication. Cubitus varus, which was once considered purely aesthetic, is now linked to chronic pain, palsy of the ulnar nerve, instability to the posterolateral, and an increased risk of other fractures. The primary objective of surgical intervention is the secure fabrication of a construct that is sufficiently stable to impede axial rotation, hyperflexion, and extension of the distal fragment, thereby averting postoperative deformity. The conclusion of numerous biomechanical studies is that crossed pins offer greater stability than lateral entry pins. It attained increased resistance to torsional and varus forces [8-10]. Despite the apparent contribution of the medial pin to construct stability, the crossed pin configuration significantly elevates the risk of ulnar nerve injury by a factor of three to five compared to lateral-only wires. To reduce the likelihood of ulnar nerve damage, for medial pinning, it has been described that a medial elbow incision, with or without ulnar nerve dissection, can reduce the risk of nerve injury. Additionally, nerve constriction in the cubital tunnel, nerve stretching over the medial pin, or anterior subluxation over the medial epicondyle may contribute to the injury [11]. Postoperative ulnar nerve examination in pediatric is challenging due to the pain and the patient is non cooperative. The examination includes Function of flexor digitorum profundus in 4th and 5th fingers, function of adductor policies (Froment's test), functions of interossei by fanning and gathering the fingers, and sensations on medial one and half fingers. It's unapplicable in younger patients so we used ultrasound assisted medial pinning to minimize the ulnar nerve risk injury in crossed supracondylar fractures pinning and examine the ulnar nerve during and post reduction. Even when the medial wire was inserted outside the ulnar groove, hyperflexion of the elbow during fracture manipulation and surgery resulted in anterior subluxation of the ulnar nerve in 5.7–17.7% of patients, according to Zaltz et al., (1996) [12]. In order to reduce the likelihood of anterior subluxation of the ulnar nerve over the medial epicondyle or to enable direct visualization of the nerve through the creation of a minor incision over the medial epicondyle, alternative surgeons extend the elbow partially prior to medial K-wire fixation [13-14]. It was considered even with making incision over the medial epicondyle doesn't make ensure the nerve protection [15]. In their systematic review, Brauer et al., (2007) provided a comprehensive overview of the available data concerning the impact of medial and lateral (medial/lateral) entry pin fixation versus lateral entry pin fixation alone on the likelihood of iatrogenic nerve injury, deformity, or loss of reduction in paediatric patients with supracondylar fractures of the humerus [16]. A total of 35 observational and clinical trials involving 2054 children were identified, comprising the following: 25 case series, 6 cohort studies, and 2 randomized trials. The probability of iatrogenic nerve injury is 1.84 times greater when all documented operative nerve injuries are considered when using medial/lateral entry pins as opposed to isolated lateral pins. A more stable configuration is achieved with medial/lateral pin entry; the likelihood of deformity or loss of reduction is 0.58 times smaller compared to lateral pin entry alone. In other study done by Carrazzone and his colleagues (2021) were conducted a meta-analysis until March 2020 including 12 trials, with a total of 930 patients with SCH fractures who were managed with crossed-wire and lateral-wire fixation. Complications and function as assessed by the Flynn criteria constituted the primary outcomes (neurologic lesions and loss of reduction) [4]. There was no discernible difference in the functional outcomes of the two groups; nevertheless, patients who underwent crossed-wire fixation were at an increased risk of iatrogenic neurologic injury. In contrast, the crossed group exhibited improved fixation stability and a reduced occurrence of fracture reduction loss. In study made by Dekker et al., (2016), revealed that the possibility of iatrogenic ulnar nerve injury was three times higher using cross wires than using lateral wires only [17].

But, in a study made by Rees et al., (2022) on 639 patients with supracondylar humerus treated with crossed pinning using mini-approach on the medial epicondyle, it revealed that the iatrogenic ulnar nerve injury rate of 0.43% was nearly 10 times lower than estimated rates from recent meta-analyses [6]. Considering all nerves, the iatrogenic injury rate for this cross-pinning cohort was also lower than the estimated iatrogenic nerve injury rate for lateral pinning. In our study, ulnar nerve was identified effectively and safely preserved by using ultrasound during the percutaneous pinning of SHF. Dynamic examination of the nerve was done intraoperatively while flexion and extension of the elbow to minimize the probability of injury due to subluxation of the nerve in the cubital tunnel. The functional outcome using Flynn's criteria was comparable to the outcome of meta-analysis done on 491 patients with supracondylar fracture by Xing et al., (2023) who reported 74.9% excellent outcomes [18]. We can recommend that percutaneous cross pinning produce satisfactory functional results, and medial penning of SCHF under guidance of ultrasound reduce the risk of iatrogenic ulnar nerve injury as it allows the visualization of nerve during medial wire insertion.

5. Limitation

The ultrasound of ulnar nerve is needy maneuver and require special training, the limited number of cases done in this thesis and require randomized control trial comparing the minimal medial condyle approach and ultrasound guided technique in protecting the ulnar nerve perioperatively.

Table 1: Flynn's criteria.

		Carrying	Total loss of range of elbow
Result	**Rating**	**Angle loss**	**motion (degrees)**
Satisfactory	Excellent	0-5	0-5
	Good	6-10	6-10
Unsatisfactory	Fair	11-15	11-15
	Poor	Over 15	Over 15

Table 2: Demographic data of the patients (n = 30).

		Patients (n = 30)
Age (years)		6.73 SD ± 1.74
Sex	**Male**	17 (56.7%)
	Female	13 (43.3 %)
Site	**Rt**	14 (46.7%)
	Lt	16 (53.3 %)

Data are presented as mean ± SD or frequency (%). Rt: right, Lt: left.

Table 3: Complications of fixation of pediatric SCFH.

	Patients (n = 30)
Ulnar nerve injury	0 (0%)
Loosening	1 (3.3%)
Malunion	0 (0%)
Stiffness	1 (3.3%)
Pin tract infection	2 (6.7%)

Data are presented as frequency (%).

Figure 1: (A) Preoperative plain x-ray elbow radiographs AP & lateral views showing SCFH, (B) Intraoperative AP view after fixation of SCFH by 2 lateral pins, (C) Intraoperative lateral view, (D) Intraoperaive detection of ulnar nerve by U/S, (E) Image of detected ulnar nerve by U/S, (F) Marking of the skin before medial pinning, (G) Insertion of medial K-wire under U/S guidance, (H). AP view after medial pinning, (I) Lateral view, (J) Postoperative plain X-ray elbow radiographs AP & lateral views showing SCFH fixed with 2 lateral diverting pins and one medial pin, (K) showing AP & lateral views 3 weeks postoperatively, and (L) showing AP & lateral views after K-wires removal 4 weeks postoperatively.

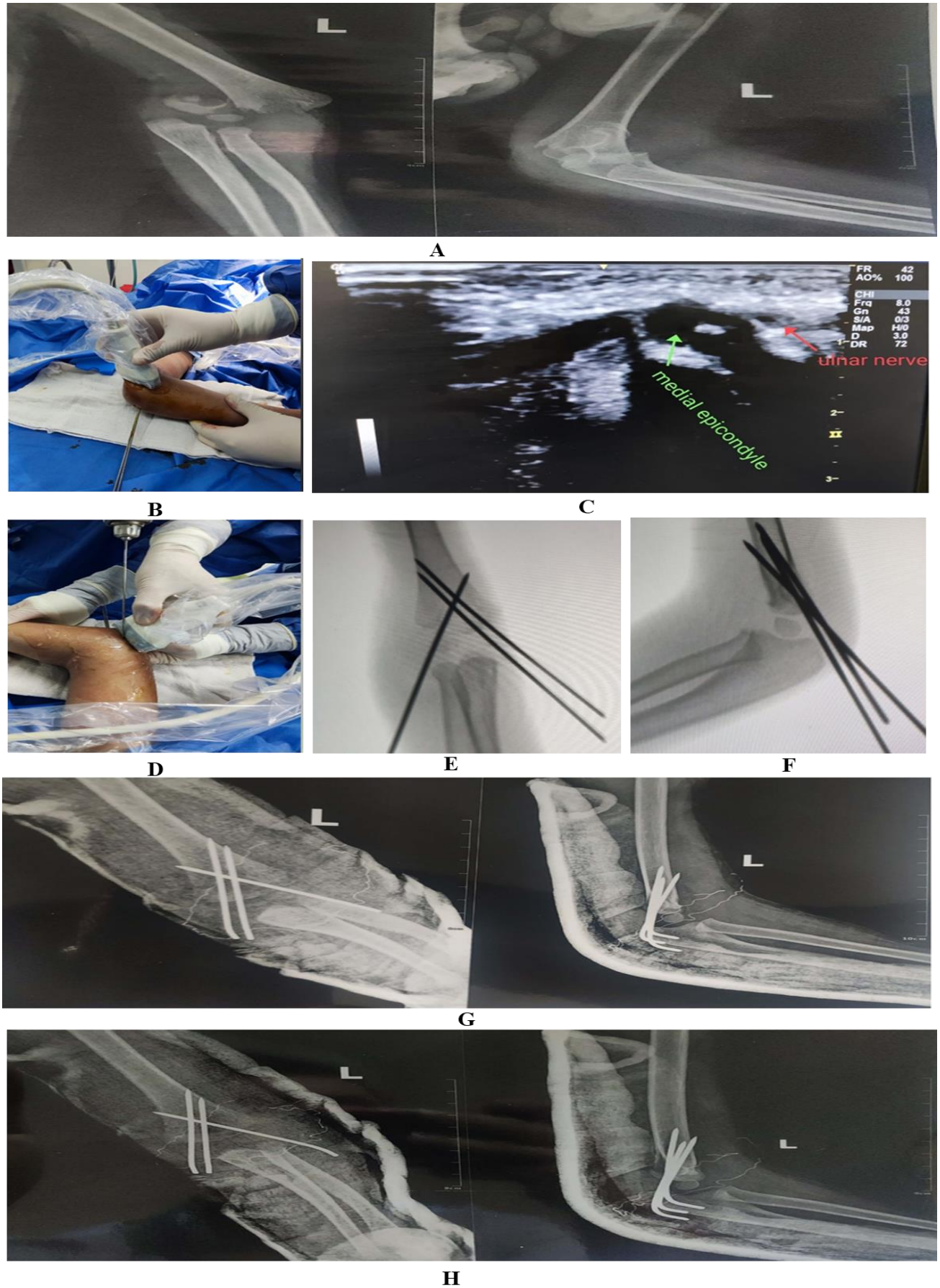

Figure 2: (A) Plain X-ray left elbow radiographs AP & lateral views showing SCFH, (B) Intraoperative detection of ulnar nerve by U/S, (C) Image of detected ulnar nerve by U/S, (D) Insertion of medial K-wire under U/S guidance, (F) AP view after medial pinning, (G) Lateral view, and (H) Postoperative plain X-ray elbow radiographs AP & lateral views showing SCFH fixed with 2 lateral diverting pins and one medial pin

Table 4: Flynn's score among patients at the final follow up.

		Patients (n = 30)
Fylnn score	**Excellent**	22 (73.3%)
	Good	3 (10%)
	Fair	3 (10%)
	Bad	2 (6.7%)

Data are presented as frequency (%).

6. Conclusions

Management of supracondylar fractures with crossed pinning provides excellent fracture stability and provides very low risk of post-operative loss of reduction and the associated risk of iatrogenic ulnar nerve injury can be avoided by using ultrasound guided pinning and application of a 1.6 to 1.8 mm drill guide in placement of medial pin after stabilizing the fracture with the lateral pin first.

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Conflict of Interest
Nil

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