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Ultrasound Guided Lateral Crossed Pin Fixation in Pediatric Supracondylar Humerus Fractures

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ABSTRACT

Objective: In our study, we aimed to test the preventability of radial nerve injury in the ultrasound-guided lateral cross pinning technique.

Methods: The study included 30 patients who were admitted to our clinic between September 2019 and September 2020 due to supracondylar humerus fractures and underwent closed reduction with the lateral cross pinning technique under ultrasonography. Demographic and clinical data of the patients were retrieved from the patient files and recorded.

Results: Fifteen (50%) of the 30 patients included in the study were girls. The patients' mean age was 59.2±33.9 months. While 3.3% of the patients had flexion-type injuries, 30.0% had Gartland Type 2, 40.0% had Type 3, and 26.7% had Type 4 injuries. Eighteen patients (60%) had fractures in their left extremities. Type 4 fractures exhibited the biggest difference among all fracture types in comparison of the arm diameters of the fractured and contralateral sides (17.1%±5.5%; p=0.013). In the comparison of the proximal K-wire and the radial nerve (PWRN) to the lateral condyle and the radial nerve (LCRN) distance ratio, the difference was the highest in Type 2 fractures (23.3%±8.0%; p=0.027). None of the patients encountered postoperative iatrogenic radial nerve injury.

Conclusion: In pediatric patients with supracondylar humerus fractures, the swelling of the extremity increases with the severity of the fracture. The ultrasound-guided lateral cross pinning technique is a reliable method in terms of ease of application and the determination of the nerve line to create a safe zone, especially in elbow injuries with excessive swelling.

Keywords: Humeral supracondylar fracture, lateral cross pinning, pediatric, ultrasonography.

Pediatrik Suprakondiler Humerus Kırıklarında Ultrasound Eşliğinde Lateral Çapraz Pinleme

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ÖZET

Amaç: Çalışmamız da Ultrasound (USG) eşliğinde lateral çapraz pinleme tekniği ile radial sinir hasarının önlenebilirliliği test edilmesi amaçlanmıştır.

Yöntem: Eylül 2019- Eylül 2020 yılları arasında kliniğimize başvuran çocuk humerus suprakondiler kırık tanısı konan ve USG eşliğinde lateral çapraz pinleme yapılan 30 hasta ile çalışma yapıldı. Hastaların demografik ve klinik verileri hasta dosyalarından elde edilerek kaydedildi.

Bulgular: Çalışmaya alınan 30 hastanın 15 (%50.0) ı kız çocuktan oluşmakta olup ortalama yaş 59.2±33.9 ay idi. 18 hasta (%60.0) sol extremiteden kırık geçirmişti. Hastaların %3,3 ü flexiyon tip, %30,0 tip 2 , %40,0 tip3 , %26,7 si tip4 yaralanma mevcuttu. Kırık tipi ile contralateral/Kırık extremite çap farkı oranı karşılaştırıldığında tip4 kırıkların çap farkı ortalamalarının daha yüksek olduğu bulunmuştur (17.1±5.5) (p=0.013). Kırık tipleri ile Wire-Radial/Condyle-Radial sinir mesafe farkı oranı karşılaştırıldığında tip 2 kırıklarında wire-sinir oranı arasındaki mesafenin en uzun olduğu bulunmuştur (23.3±8.0) (p=0.027). Hiçbir hastada postoperatif iyatrojenik radial sinir yaralanması görülmemiştir.

Sonuç: Pediatrik Suprakondiler humerus kırıklı hastaların kırık tipi ile extremite şişlik oranının arttığı görülmektedir. USG eşliğinde lateral çapraz pinleme tekniği uygulama kolaylığı ve özellikle aşırı şişlik gözlenen dirsek yaralanmalarında sinir hattının belirlenip güvenli bir alan oluşturması açısından güvenilir bir yöntem olarak karşımıza çıkmaktadır.

Anahtar Kelimeler: Humerus suprakondiler kırık, lateral çapraz pinleme, pediatrik, ultrasonografisi.

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Introduction

Supracondylar fractures of the humerus are common traumas during childhood and are associated with malunion, neurovascular complications, and morbidity due to compartment syndrome. These fractures account for 16% of all pediatric fractures and two-thirds of the hospitalizations for pediatric elbow injuries.[1] A correct understanding of supracondylar fractures is essential for the success of the treatment and the reduction of complications.[2]

Nondisplaced fractures are first treated with a posterior splint followed by a long arm cast. Closed reduction and percutaneous pinning are the treatment of choice for displaced or unstable fractures. Percutaneous pinning may be performed using the lateral-medial cross, lateral divergent, or lateral cross technique. While these techniques have been compared in several studies in the literature, debates about the advantages and disadvantages of these techniques still continue.[3,4] The main advantage of using the cross pin technique is to provide greater stability, which prevents secondary fracture displacement and misalignment. However, it has been reported that the prevalence of ulnar nerve injury increases by 4.3 times with lateral-medial cross pinning.[4]

Some authors suggested that the best way to prevent iatrogenic ulnar nerve injury was to avoid medial nailing and recommended lateral cross pinning as an alternative method.[5-7] However, this method raises concerns about the risk of radial nerve injury in the supracondylar region created by the wire sent from the proximal.[8]

In this study, our primary aim was to evaluate the feasibility and reliability of the ultrasound-guided lateral cross pinning technique in pediatric supracondylar fractures. We also aimed to determine the relationship of the proximal wire with the radial nerve and assess its effectiveness in reducing the risk of iatrogenic nerve injury. Considering that the study to be conducted in this context is the first in the literature, our results can provide valuable contributions to the literature.

Patients and Methods

The study was started following the approval of the Sivas Cumhuriyet University Non-Interventional Clinical Research Ethics Committee (Decided Number:2020-10/06, Date:21.10.2020). Thirty-two patients admitted to the Department of Orthopedics and Traumatology at the Faculty of Medicine of Sivas Cumhuriyet University due to supracondylar humerus fracture between September 2019 and September 2020 were included in the study. One patient was later excluded due to preoperative radial nerve palsy and another due to the requirement of open reduction. The study was continued with a total of 30 patients who underwent closed reduction with the lateral cross pinning technique under ultrasonography (USG). Demographic and clinical information of the patients including age, gender, fracture type according to the modified Gartland classification,[9,10] fracture side, concomitant injuries, arm diameters of the fractured and contralateral sides, the distance between the lateral condyle and the radial nerve (LCRN), the distance between the proximal K-wire and the radial nerve (PWRN), duration of surgery, the time between fracture diagnosis and surgery, and postoperative complications of the nerve were retrieved from the patient files and recorded.

Surgical technique

All patients were operated on in the supine position under general anesthesia by the same pediatric orthopedic surgeon after the surgery conditions were met. Before the surgery, the area where the radial nerve laterally crossed the humerus in the fractured extremity was determined and marked under USG. After assessing the quality of the closed reduction with fluoroscopy, Kirschner wires (K-wires) were sent from the lateral condyle to the humeral body. A K-wire was sent from the proximal shaft of the humerus to the medial condyle using the appropriate K-wire configuration, provided that the advancement line was below the mark determined under the fluoroscopic guidance. The quality and stability of the reduction were checked under fluoroscopy (**Fig. 1**). The LCRN distance where it laterally crossed the humerus, the PWRN distance, the arm diameter at the marked radial nerve level in the fractured extremity, and the arm diameter at the level where the radial nerve crossed the humerus in the contralateral extremity were measured and recorded (**Fig. 2**). The surgery was ended after placing the patients in a long arm cast at 70 degrees.

Statistical analyses were carried out using the SPSS v.23 software (SPSS Inc., Chicago, IL, USA). Descriptive statistics were expressed as percentage, mean and standard deviation. The Kruskal-Wallis test was employed in analyzing the relationship between the fracture type and the duration of surgery, the arm diameter difference between the fractured/contralateral side, and the PWRN to LCRN distance ratio, while correlation analysis was used in the evaluation of the relationship between the arm diameter difference between the fractured/contralateral side and the PWRN/LCRN distance ratio. The level of significance was assumed at the $p<0.05$ level.

Results

Fifteen (50%) of the 30 patients included in the study were girls. The patients' mean age was 59.2±33.9 months (range: 17.0 to 137.0 months). Twelve (40.0%) of the participants had Type 3 fractures, while 18 patients (60%) had fractures in their left extremities. Two patients (6.7%) had concomitant ipsilateral torus fractures of the distal radius. The mean diameter of the fractured arm was 20.7±3.2 cm (range: 17.0 to 33.0 cm), while the mean diameter of the contralateral arm was 18.3±3.0 cm (range: 15.0 to 30.5 cm). The mean difference between the diameters of the fractured and contralateral arms was

Fig. 1. Supracondylar humerus fracture in a 5-year-old girl. A. Using ultrasonography, the place where the radial nerve crosses the humerus is determined (black arrows: safe zone). B. Ultrasonogram of the patient (white arrow: radial nerve, blue circle: humerus). C. Preoperative AP X-ray image. D. Preoperative lateral X-ray image. E. Intraoperative AP fluoroscopy image. F. Intraoperative lateral fluoroscopy image.

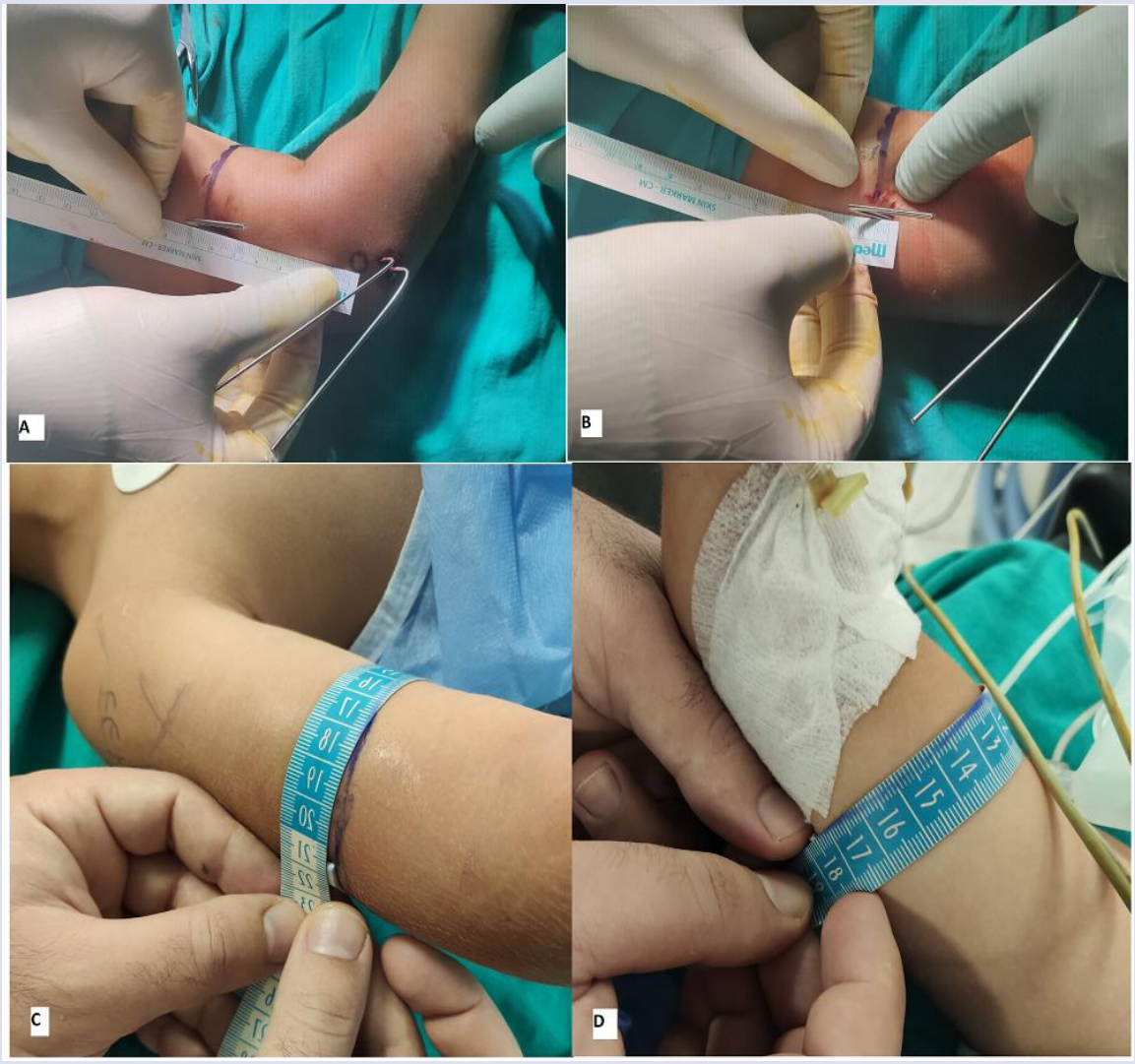

Fig. 2. Postoperative measurements. A. Lateral condyle-radial nerve (LCRN) distance. B. Proximal-lateral K-wire-radial nerve (PWRN) distance. C. Arm diameter in the fractured extremity. D. Arm diameter in the contralateral extremity.

13.2%±6.5% (range: 2.8% to 30.5%). The mean LCRN distance was 6.3±1.5cm (range: 4.0 to 11.1 cm), whereas the mean PWRN distance was 1.0±0.6 cm (range: 0.4 to 3.5 cm). The mean PWRN/LCRN distance ratio was 17.1%±7.7% (range: 6.2% to 38.8%). The mean duration of surgery was 39.8±11.6 minutes (range: 25.0 to 60.0 minutes). The time elapsed between the diagnosis of fracture and the surgery was over six hours in 56.7% (n=17) of the patients. Pin tract infection developed in 20.0% (n=6) of the patients. Recovery after the removal of the K-wire was achieved with appropriate antibiotic therapy (Table 1).

Since there was only one patient with a flexion-type fracture in the study, this was not included in the analyses. Type 4 fractures had a higher duration of surgery than other fracture types, with a mean duration of 45.0±8.8 minutes (p=0.76). Again, Type 4 fractures had the biggest difference among all fracture types in the comparison of the arm diameters of the fractured and contralateral sides (17.1%±5.5%), exhibiting a statistical significance (p=0.013). In comparison of the PWRN to LCRN distance ratio, the difference was the highest in Type 2 fractures (23.3%±8.0%; p=0.027) (Table 2). There was a negative, moderate, non-significant correlation between the arm diameter difference between the fractured/contralateral side and the PWRN/LCRN distance ratio (r=-0.34, p>0.05).

Table 1. Descriptive characteristics of the study patients (n=30).

	Percentage (n)	Mean±SD	Range
Gender			
Female	50.0 (15)		
Male	50.0 (15)		
Age (months)		59.2±33.9	17.0-137.0
Fracture type			
Flexion	3.3 (1)		
Type 2	30.0 (9)		
Type 3	40.0 (12)		
Type 4	26.7 (8)		
Fracture side			
Right	40.0 (12)		
Left	60.0 (18)		
Concomitant injuries			
Yes	6.7 (2)		
No	93.3 (28)		
Arm diameter of the fractured side (cm)		20.7±3.2	17.0-33.0
Arm diameter of the contralateral side (cm)		18.3±3.0	15.0-30.5
Arm diameter difference between the fractured/contralateral side (%)		13.2±6.5	2.8-30.5
LCRN distance (cm)		6.3±1.5	4.0-11.1
PWRN distance (cm)		1.0±0.6	0.4-3.5
PWRN/LCRN distance ratio (%)		17.1±7.7	6.2-38.8
Duration of surgery (minutes)		39.8±11.6	25.0-60.0
Time to surgery			
≤ 6 hours	43.3 (13)		
6-12 hours	56.7 (17)		
Postop complications			
Yes	20.0 (6)		
No	80.0 (24)		

LCRN: lateral condyle-radial nerve, PWRN: proximal wire-radial nerve.

Table 2. Duration of surgery, arm diameter difference between the fractured/contralateral side, and the PWRN/LCRN distance ratio according to fracture types.

Fracture type	Duration of surgery (mean±SD)	Arm diameter difference between the fractured/contralateral side (mean±SD)	PWRN/LCRN distance ratio (mean±SD)
Type 2	34.4±10.7	8.2±3.3	23.3±8.0
Type 3	38.7±11.8	14.8±6.9	14.4±6.5
Type 4	45.0±8.8	17.1±5.5	14.1±5.8
p	0.76	**0.013**	**0.027**

LCRN: lateral condyle-radial nerve, PWRN: proximal wire-radial nerve.
Significant p values are written in bold.

Discussion

The strength of our study is its presentation of a USG-guided lateral cross pinning method for the first time in the literature. In addition, radial nerve distance measurements were made according to fracture types and the changes in the arm diameter due to edema. Closed reduction and percutaneous pinning are widely accepted methods in the treatment of displaced supracondylar fractures of the humerus in children. Although different configurations exist for fixation, biomechanical studies suggest cross-configuration as the most suitable one for stabilization.[11,12] The main purpose of the current study is based on determining the location of the radial nerve with the help of USG and minimizing the iatrogenic radial nerve damage during the advancement of the wire from the proximal to the lateral.

Ultrasonography is widely used in musculoskeletal diseases. Recently, the tendency among orthopedists to use USG in the diagnosis and follow-up phases of pediatric patients has increased.[13-15] Soldado et al. designed their study on the detection of the ulnar nerve with USG and then cross insertion of the K-wire.[15] The authors did not record any iatrogenic nerve manifestations, however, they mentioned of technical difficulties since they had to

manipulate the ulnar nerve when sending the wire from the medial. The advantages of the technique are that the patients who underwent USG during the study are performed by us and that the evaluation is easy. This ease depends on the fact that the anatomical region where the radial nerve crosses the distal humerus is located on a flat surface increases the ease of USG and the comprehensibility of the learning curve.

Some authors recommend the lateral cross pinning method as it prevents ulnar nerve injury and is as effective as cross pinning.[7] However, the advancement of the wire from the proximal to the lateral in lateral cross pinning poses a risk for radial nerve injury.[16] Superolateral insertion of the pin to reduce nerve injury risks has been recommended as an alternative in studies that are based on clinical experience and radiological analysis.[17-19]

In a study in which radial nerve damage occurred as a result of lateral cross pinning, the authors mentioned that the technique is not widely used and the literature information about the 'safe zone' is scarce.[16] In addition, the authors focused on the need to be attentive when sending the wire and the need to determine the location with USG if necessary. We believe that our study will contribute to the literature in this context. In our study, the safe zone was determined intraoperatively for each patient, so that the phenotypic traits of the patient are evaluated and individual safe zones are determined. These assessments helped us provide a standardized approach to individual independent measurements and parameters such as age, gender, and trauma-related swelling. Since the measurements were performed during anesthetic procedures, it did not cause any loss of extra time or cost, while no neurological damages were observed in the patients.

Symptoms such as extensive ecchymosis, soft tissue swelling, and skin shrinkage in humeral supracondylar fractures indicate severe trauma.[20] The swelling can cause difficulties in determining the anatomical location during wire delivery. We can conclude from our study that as the severity of the trauma increases, the diameter of the fractured arm increases significantly compared to the contralateral arm. Although this increase is considered an expected finding, a significant decrease is observed between the distance of the superolateral K-wire and the radial nerve after reduction. This is explained by the view that the superior K-wire moves proximally in a swollen arm to provide the appropriate configuration. By creating a safe zone under ultrasonography guidance and keeping the wire within this zone, the nerve damage was prevented.

Despite reports suggesting that the distance between the radial nerve and the proximal wire is sufficient and that it will not cause iatrogenic nerve damage, some researchers asserted that the radial nerve may be injured during the placement of the proximal wire.[19,21] We did not encounter any nerve damage in our patients postoperatively. However, we observed that the proximal wire approached the upper limit of the safe zone with a significant increase in arm diameter, especially in patients with Type 4 fractures. This has shown us that the risk of nerve injury may increase further in patients of advanced trauma with an increased arm diameter and that USG is of great help in this regard.

The study's retrospective design and the small number of patients included in it may be considered a limitation. Further larger prospective series is mandatory to support our results.

In conclusion

The detection of the radial nerve by USG is an easy and applicable method in pediatric patients with supracondylar humerus fractures. The swelling of the extremity increases with the severity of the fracture in pediatric patients with supracondylar humerus fractures. This situation decreases inversely with the distance of the proximal K wire from the radial nerve. The ultrasound-guided lateral cross pinning technique is a reliable and effective method in terms of determining the nerve line and creating a safe zone, especially in elbow injuries with excessive swelling.

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Authors' Contributions:

SK: Conceptualization, Data curation, Formal Analysis, Writing – original draft.

OP: Data curation, Writing –review & editing.

MYA: Formal Analysis, Writing – original draft.

BA: Data curation, Writing – review & editing.

SA: Writing – review & editing.

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