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Medial elbow approaches for coronoid fractures: risk to the ulnar nerve

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A R T I C L E I N F O

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Level of evidence: Level III; Retrospective Cohort Comparison; Treatment Study

Background: Coronoid fractures often require open reduction internal fixation (ORIF) to restore elbow stability. The flexor pronator split, flexor carpi ulnaris (FCU) split, and Taylor and Scham (T&S) approaches are frequently used medial approaches to access the coronoid. The ulnar nerve can be released or transposed when performing these exposures. The optimal medial surgical approach and management of the ulnar nerve has not been clearly defined. The purpose of this study was to compare postoperative ulnar nerve complications in coronoid fractures undergoing ORIF following a medial surgical approach and ulnar nerve release or transposition.

Methods: A retrospective review of 91 patients with coronoid fractures treated with ORIF using a medial approach from 2004 to 2022 was performed at three academic medical centers. Patients $\geq$ 18 years of age who sustained coronoid fractures with or without associated injuries were included. Patient charts and perioperative imaging were reviewed. Patient demographics, fracture classification, associated injuries, surgical approaches, ulnar nerve management, and postoperative complications were recorded. Primary outcomes assessed were signs and symptoms of postoperative ulnar nerve neuropathy.

Results: The mean age of the cohort was 45 $\pm$ 16 years, 71% were males, with a mean length of follow-up of 16 $\pm$ 22 months. Of the 91 coronoid fractures, 69 were anteromedials, eight were tips, and 14 were basal types. The incidence of preoperative ulnar neuropathy was 5% (n = 5). The incidence of postoperative ulnar neuropathy was 33% (n = 30) of which 55% (n = 16) completely resolved by final follow-up. The rate of postoperative ulnar neuropathy was not significantly different between in situ release 30% (n = 9) or transposition of the ulnar nerve 34% (n = 20), (P = .64). There was a significantly higher rate of postoperative resolution with transposition (70%) versus in situ release (22%), (P = .045). The rate of postoperative ulnar neuropathy was not significantly different between the FCU, T&S, or flexor pronator split approaches, (P = .331). Finally, the rate of neuropathy resolution was not significantly different between medial approaches (P = .46).

Conclusion: There was no statistical difference in the incidence of postoperative ulnar nerve complications with ulnar nerve transposition or in situ release following coronoid fixation. However, transposing the nerve resulted in a higher rate of neuropathy resolution. While the incidence of postoperative ulnar nerve dysfunction is high following coronoid fixation when using a medial surgical approach, it was similar with the FCU, T&S, and flexor pronator split approaches. Larger cohorts and randomized clinical trials are needed to confirm these findings.

The coronoid process functions as a primary bone stabilizer of the ulnohumeral joint with its various fracture morphologies being associated with specific patterns of traumatic elbow instability.[6,16,24] Larger coronoid fractures typically require open

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reduction and internal fixation (ORIF) to restore elbow stability. This is especially seen in anteromedial and basal coronoid fractures.[14,16] Various medial approaches can be used to provide adequate visualization, stabilization, and fixation of fracture fragments with isolation and protection of the ulnar nerve being an integral step. Exposures such as the flexor pronator split or Smith approach utilize the internervous plane between the median and ulnar nerves by identifying the superficial raphe between the flexor carpi ulnaris (FCU) and palmaris longus and flexor digitorum superficialis (FDS) in the deep plane.[23] The extended medial elbow approach which utilizes Smith's interval and is extended proximally by elevating the flexor-pronator mass from the capsule has been shown to provide the most visualization of coronoid surface area.[11] The FCU-split follows the ulnar nerve and approaches the natural plane between the two heads of the FCU providing exposure for fractures that involve the sublime tubercle. However, an increased incidence of postoperative ulnar neuropathy has been reported with this approach.[6,13] This complication has the potential for prolonged or incomplete recovery.[8,17] Finally, the Taylor and Scham (T&S) approach which allows visualization of the structures posterior to the medical collateral ligament (MCL), uses the interval posterior to the FCU and requires elevation of the flexor-pronator mass from the medial ulna.[1]

Much of the literature regarding intraoperative ulnar nerve management at the elbow is in the setting of distal humerus fractures where high rates of postoperative neuropathy have been reported.[7] Furthermore, there is a lack of consensus as to whether in situ release or transposition is the best option for ulnar nerve management.[5,7] More specifically, the risk to the ulnar nerve from medial surgical approaches to the coronoid or management of the ulnar nerve has not been clearly defined. Therefore, this study sought to compare postoperative nerve complications in coronoid fractures undergoing ORIF following a FCU, T&S, or flexor pronator split approach and ulnar nerve release or transposition.

Materials and methods

A retrospective review of coronoid fractures treated with ORIF using a medial elbow approach by seven fellowship trained surgeons at three academic medical centers over a period from 2004 to 2022 was performed. This study was approved by our institutional research ethics boards.

Inclusion and exclusion criteria

Coronoid fractures with or without associated injuries that underwent ORIF in patients ≥ 18 years of age were included in the study. Only coronoid fractures fixed using a medial approach were included. Fractures which did not have accessible CT imaging were excluded. Patient charts and perioperative imaging was reviewed by three investigators. Imaging was accessed through the Picture Archiving Communication System. Patient demographics, fracture classification, associated injuries, medial surgical approaches, ulnar nerve management, and postoperative complications were recorded.

Surgical interventions

All surgeries were performed by or under the direct supervision of a senior surgeon. Intravenous prophylactic antibiotics were administered preoperatively. All patients underwent a general anesthetic or peripheral block. A medial approach was used for fixation of the coronoid process. Concomitant lateral collateral ligament or MCL repair was performed based on the fracture pattern, instability, and surgeon discretion. A standard medial incision centered over the MCL or a posterior skin incision with a full-thickness fasciocutaneous medial flap was developed. The ulnar nerve was identified proximally at the intermuscular septum and traced to the cubital tunnel between the two heads of the FCU and protected throughout the procedure.

The flexor pronator split

The muscle-split was performed through the posterior one third of the common flexor bundle and the anterior fibers of the FCU muscle. More specifically, at the raphe between the FCU and palmaris longus superficially and FCU and FDS in the deep interval. The raphe was identified one centimeter distal to the MCL insertion and split down to he level of the MCL and developed proximally toward the medial epicondyle. The ulna was accessed through subperiosteal dissection and the ulnar nerve was gently retracted with the posterior portion of the FCU.[11,23] Partial to complete release of the anterior flexor pronator origin off of the medial epicondyle may be required to improve coronoid visualization.

The FCU − split

The ulnar nerve was decompressed down to the split between the heads of the FCU. The fibers were split to approximately one centimeter distal to the sublime tubercle. The flexor pronator mass was retracted anteriorly exposing the sublime tubercle, MCL, and coronoid while protecting the first motor branch of the ulnar nerve. Proximally, the flexor pronator mass was released approximately one centimeter off the medial epicondyle leaving a cuff of tissue for later repair. The ulnar head of the FCU was partially elevated from the capsule and ulna and retracted posteriorly. Partial to complete release of the anterior flexor pronator origin off the medial epicondyle may be required to improve coronoid visualization.

Taylor and Scham

An incision was made along the triangular subcutaneous border of the ulna, raising the periosteum medially.[25] The muscular origin of the flexor digitorum profundus was elevated and the ulnar head of the FDS and the deep head of the pronator teres were freed. Exposure was continued anteriorly and proximally until identification of the anterior margin of the coronoid and the sublime tubercle. Partial to complete release of the anterior flexor pronator origin off the medial epicondyle may be required to improve coronoid visualization.

Ulnar nerve management

After fixation of the coronoid, the ulnar nerve was addressed in one of two ways.[7] In situ placement of the ulnar nerve had the nerve maintained in its anatomic position in the cubital tunnel. Patients who underwent transposition of the ulnar nerve had it placed subcutaneously anterior to the medial epicondyle. The intraoperative decision to transpose the ulnar nerve was based on the treating surgeon's discretion.

Postoperative care

A posterior splint was applied at the conclusion of the operation with the elbow at 90 degrees of flexion and neutral rotation. The splint was removed at 10-14 days postoperatively with an overhead rehabilitation protocol initiated focusing on stable range of motion. A resting 90-degree splint was also provided to the patient to be used between exercises for the first 6 weeks. At six weeks active range of motion was allowed. At three months postoperative strengthening was started.

Outcome assessments

Our primary outcome was recorded signs or symptoms of postoperative ulnar nerve neuropathy assessed during

Table I
Patient demographics and fracture characteristics.

	Medial approach (n = 91)
Male	65 (71%)
Age (y)	45 ± 16
Length of follow-up (mo)	16.2 ± 21.7
Preoperative ulnar nerve status:	
Sensory loss/paresthesia	5 (5%)
Weakness	0
Fracture dislocation	42 (46%)
O'Driscoll fracture type:	
Anteromedial	69 (76%)
Tip	8 (9%)
Basal	14 (15%)
Fixation type:	
Screw/anchor/wires	21 (23%)
Plate fixation	70 (77%)

postoperative follow-up appointments. Ulnar neuropathy was defined as paresthesia's, weakness in the ulnar nerve distribution, or decreased sensation.[13] Fracture characteristics, surgical approach, and fixation type were recorded. The development of postoperative heterotrophic ossification was assessed on anteroposterior and lateral radiographs at subsequent follow-ups. We assessed and compared postoperative neuropathy between medial approaches and intraoperative ulnar nerve management. Finally, the resolution of neuropathy at final follow-up was recorded.

Statistical plan

Descriptive statistics are presented as mean values and standard deviations. For categorical data, a chi-squared or Fischer exact test was used. Multinominal logistic regression analysis was also performed defining postoperative neuropathy as the dependent variable, medial approach as the independent variable, and intraoperative nerve management as the covariate. The level of significance was set at $P < .05$. Data analysis was performed using IBM SPSS for Mac OS X, Version 23 (IBM Corp., Armonk, NY, USA).

Results

A total of 163 patients who underwent ORIF for coronoid fractures by seven fellowship trained surgeons from 2004 to 2022 were reviewed. Ninety-one fractures met our inclusion criteria. The mean age in our cohort was 45 (range: 18-84) years, of which 71% were males. The mean length of follow-up was 16 (range: 1-152) months. Patient demographics are listed in (Table I). Of the 91 coronoid fractures, 69 were anteromedial, eight were tip, and 14 were basal types. The incidence of preoperative ulnar neuropathy was 5% (n = 5). One of these patients had documented signs of ulnar and radial nerve paresthesia preoperatively. No patient with preoperative ulnar nerve symptoms had motor weakness. Overall, 30 patients demonstrated signs of postoperative ulnar neuropathy (33%). Of these only one patient had documented signs of weakness in the ulnar nerve distribution and the rest had pure sensory parasthesias. Overall, the FCU-split approach (n = 44) was the most common surgical approach performed. Following this was the flexor pronator split (n = 32) and T&S (n = 15). There was no significant difference in postoperative neuropathy based on fixation type, $P = .17$.

Intraoperative nerve management

Thirty-two patients (35%) had in situ decompression of the ulnar nerve, and protection of the nerve with gentle retraction during the procedure with the nerve maintained in the cubital tunnel at the conclusion of the operation (in situ group), while 59 patients (65%) had the nerve transposed anteriorly at the end of the procedure (transposition group). The incidence of postoperative ulnar neuropathy (Table II) was not significantly different between the in situ release (30%) or the transposition groups (34%), $P = .64$. The symptoms of postoperative ulnar neuropathy completely resolved in 55% of the patients by final follow-up. There was a significantly higher rate of postoperative symptom resolution with transposition (14/20, 70%) versus in situ release (2/9, 22%), $P = .022$. The one patient with postoperative weakness had their symptoms resolve by final follow-up. Only one patient (20%) with documented preoperative ulnar neuropathy had resolution of their symptoms.

A subgroup analysis was performed after removing patients with preoperative neuropathy (Table III). The incidence of postoperative ulnar nerve neuropathy was still not significantly different between in situ release (26%) or transposition (30%), $P = .81$. There was a significantly higher rate of postoperative neuropathy resolution with transposition (82%) versus in situ release (13%), $P = .013$.

FCU split vs. flexor pronator split vs. T&S

Tables IV and V outline the incidence of postoperative neuropathy, associated fracture classification, and ulnar nerve management by medial approach. The flexor pronator split group had the highest incidence of postoperative neuropathy (37%), followed by the FCU split (33%), and T&S (22%); however, this was not statistically different ($P = .331$). Regression analysis found that the rate of neuropathy resolution was not significantly different between medial approaches ($P = .46$). Subgroup analysis was performed after removing patients with preoperative neuropathy. Four of these patients underwent a flexor pronator split approach, and one underwent a FCU split. Repeat regression analysis still yielded no significant differences. There were no differences in the rate of heterotrophic ossification development between the FCU split, T&S, and flexor pronator split ($P = .77$).

Discussion

Our study investigated the development of postoperative ulnar neuropathy following operative fixation of coronoid fractures using a medial elbow approach with differing intraoperative ulnar nerve management options. We observed that there were no statistical differences in postoperative ulnar nerve complications with ulnar nerve transposition or in situ release. However, transposing the ulnar nerve did lead toward a significantly higher rate of neuropathy resolution. Finally, postoperative ulnar neuropathy was not significantly different between the FCU, T&S, or flexor pronator split approaches.

It is generally accepted that larger coronoid fractures often require open reduction and internal fixation to maintain elbow stability given its role in resisting posterior translation and varus rotation of the ulna in relation to the distal humerus.[3,6,13,14,19,20,26] These injuries, particularly anteromedial facet fractures have a predisposition to rapid posttraumatic arthritis secondary to incongruity of the medial ulnohumeral joint, and therefore require adequate exposure often through a medial approach.[11,16,20] Various medial surgical approaches exist, each providing different levels of exposure to the coronoid with decision making based on fracture morphology, concomitant ligamentous injury, and surgeon discretion.[11] However, extensive ulnar nerve dissection and additional translocation or prolonged retraction are inherent to some approaches which can lead to postoperative neuropathy.[8,18,25]

Table II
Postoperative ulnar neuropathy & resolution.

	Intraoperative management of ulnar nerve		
	In situ (n = 30)	Transposition (n = 58)	
Postoperative neuropathy	9 (30%)	20 (34%)	*P* = .64
Resolution of neuropathy by final follow-up	2/9 (22%)	14/20 (70%)	*P* = .022

n = 3 had no decompression or transposition of the ulnar nerve.

Table III
Postoperative ulnar neuropathy & resolution – preoperative neuropathy excluded.

	Intraoperative management of ulnar nerve		
	In situ (n = 28)	Transposition (n = 55)	
Postoperative neuropathy	8 (26%)	17 (30%)	*P* = .81
Resolution of neuropathy by final follow-up	1/8 (13%)	14/17 (82%)	*P* = .013

Overall, the rate of postoperative ulnar neuropathy in our fracture cohort was quite high with a rate of 33%. Ulnar neuropathy is commonly recognized as a complication after surgical treatment of complex acute elbow fractures. It is theorized that injury occurs at the time of surgery secondary to dissection, prolonged retraction, or direct compression from prominent hardware.[2] The predominance of literature regarding this is in the context of distal humerus injuries with incidences of ulnar nerve symptoms from 0% to 51%.[22] Most notably, Dehghan et al [7] randomized 58 patients with distal humerus fractures to either in situ release or transposition showing no difference between the two management options similar to the findings of the current study. Furthermore, they demonstrated a similar incidence of 36% postoperative ulnar nerve motor and sensory neuropathy through nerve conduction testing. Chen et al retrospectively evaluated 89 patients who underwent open reduction and internal fixation for distal humerus fractures with or without subsequent ulnar nerve transposition and found a 33% incidence of neuritis associated with transposition which is similar to our cohorts.[5] They defined ulnar nerve neuritis as any subjective symptoms or physical findings such as parasthesias, numbness, or intrinsic weakness.

Only 55% of our noted ulnar neuropathy resolved completely by final follow-up. Typically injury-related nerve palsies resolve; however, recovering from ulnar nerve palsies in the postoperative setting can be prolonged and incomplete.[22] We did find a significantly higher rate of ulnar neuropathy resolution in patients who underwent a transposition versus those who did not. Ulnar nerve transposition may be protective by diminishing postoperative scarring which may occur by leaving the nerve adjacent to the coronoid and surgical interval and avoiding tension and compression on the nerve during the surgery by moving it away from the fracture manipulation and fixation. Furthermore, less mechanical compression of the nerve against the posterior aspect of the medial epicondyle during flexion and less risk of ulnar nerve instability related irritation occurs. Currently, there is no consensus or preferred ulnar nerve management during a medial approach to the coronoid; however, transposition in the setting of distal humerus fractures does not seem to have a protective effect in the resolution of neuropathy.[21] This was further illustrated in a recent meta-analysis by Li et al, who evaluated eight randomized control trials in their subgroup analysis finding no differences in postoperative ulnar neuropathy between anterior transposition or not in distal humerus fractures.[15]

It is widely accepted that a medial approach is required to obtain an anatomical reduction of large coronoid fractures to prevent

Table IV
Medial approach and fracture classification.

Medial approach	Fracture classification (O'Driscoll)	Postoperative neuropathy (n = 30)	Neuropathy resolution
Flexor pronator split (n = 32)	Tip (n = 3) Anteromedial (n = 25) Basal (n = 3)	13 (37%)	4/13 (31%)
FCU split (n = 44)	Tip (n = 3) Anteromedial (n = 36) Basal (n = 5)	13 (33%)	11/13 (85%)
T&S (n = 15)	Tip (n = 2) Anteromedial (n = 7) Basal (n = 6)	3 (22%)	1/3 (33%)
		P = .331	*P* = .46

FCU, flexor capri ulnaris; *T&S*, Taylor and Scham.
No significant differences in postoperative neuropathy between FCU, T&S, and flexor pronator split approaches, *P* = .331. No significant association between medial approach and resolution of neuropathy, *P* = .46.

Table V
Medial approach and ulnar nerve management.

Medial approach	Ulnar nerve management	Postoperative neuropathy (n = 30)	Neuropathy resolution
Flexor pronator split (n = 32)	In situ: 18 Transposition: 13	In situ: 8 Transposition: 5	In situ: 2 Transposition: 2
FCU split (n = 44)	In situ: 11 Transposition: 33	In situ: 0 Transposition: 13	In situ: 0 Transposition: 11
T&S (n = 15)	In situ: 3 Transposition: 12	In situ: 1 Transposition: 2	In situ: 0 Transposition: 1
		P = .331	*P* = .46

FCU, flexor capri ulnaris; *T&S*, Taylor and Scham.
Flexor Pronator: n = 3 had no decompression or transposition of the ulnar nerve. None of these went onto neuropathy.

instability and posttraumatic osteoarthritis.[11,14,16,18,19] More specifically, anteromedial fractures comprised 76% of our cohort often necessitating a medial exposure. We noted no differences in postoperative neuropathy between the FCU-split, T&S, and flexor pronator split approaches. An absolute incidence of 33% postoperative neuropathy was found in our FCU-split group compared to 56% in Lee et al's cohort.[13] They clinically compared the Hotchkiss over the-top approach to the FCU-split finding an increased incidence of postoperative ulnar nerve neuropathy in the latter. This is not overly surprising as exposure of the ulnar nerve is not required in the over-the-top approach because it remains with the humeral and ulnar heads of the FCU.[10] In contrast during the FCU-split approach the nerve is retracted posteriorly after in situ decompression to facilitate exposure of the coronoid and to protect it during internal fixation.[4,18] Prolonged retraction or stretching of the ulnar nerve or its branches can lead to neuropathy. However, there is a trade-off with increased exposure of the coronoid versus risk of neuropathy. Cadaveric studies have demonstrated that the FCU-split approach offers increased osseous visualization including the sublime tubercle and MCL which is required in anteromedial fracture subtype 3 and basal coronoid fractures.[11,12]

Bates et al[1] recently performed a cadaveric study comparing coronoid exposure in the modified T&S versus the FCU-split approach finding a larger average area of exposure in the T&S approach. They performed a modification to the original T&S approach by routinely transposing the ulnar nerve anteriorly to the medial epicondyle and elevating it with the FCU muscle belly. Transposing allowed radial retraction of the flexor-pronator mass with decreasing tensioning of the nerve and its branches. The majority of T&S approaches in our fracture cohort included transposition of the ulnar nerve; however, no significant differences were identified in postoperative neuropathy. Though we observed a higher rate of neuropathy resolution in the FCU split compared to the other two medial approaches, this observed difference in resolution did not reach significance.

This study has limitations which are inherent to its retrospective design. We assessed the presence of neuropathy as a dichotomous outcome from a chart review and did not use a validated outcome measure such as a the Gabel and Amadio ulnar nerve entrapment scale.[9] This might have provided further clarity as this scale differentiates degrees of sensory and motor neuropathy as well as quantifies pain. The primary focus of the study was to assess the incidence of ulnar nerve neuropathy dependant on approach and intraoperative nerve management. As such, we did not collect postoperative clinical/functional data. Furthermore, these patients in our study cohort were treated by surgeons with high-volume elbow practices. It is unclear whether similar incidences of postoperative neuropathy would be reproduced by lower volume surgeons. Finally, by solely focusing on medial approaches to address this fracture type, this led to decreased numbers in our regression analysis increasing the probability of a type two error. Nevertheless, to our knowledge, this is the largest coronoid cohort study and the first to compare these three surgical approaches and assess postoperative neuropathy. This information can aid surgeons when choosing surgical approaches and counseling their patients regarding outcomes.

Conclusion

This retrospective cohort study demonstrated no differences in postoperative ulnar nerve complications with ulnar nerve transposition or in situ release following coronoid fixation using a medial surgical approach. However, transposing the nerve resulted in a higher rate of neuropathy resolution. While the incidence of postoperative ulnar nerve dysfunction is high following coronoid fixation, it was similar with the FCU, T&S, and flexor pronator split approaches. Larger cohorts and randomized clinical trials are needed to confirm these findings.

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