11-1-2023

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Recommended Citation

Payne, Emma R; Wall, Lindley B; Baker, Stacy; Calhoun, Valeri; Roberts, Summer; and Goldfarb, Charles A, "Outcomes of therapy and ulnar nerve transposition for elbow stiffness after pediatric medial epicondyle fractures." Journal of Hand Surgery Global Online. 5, 6. 744 - 750. (2023).
https://digitalcommons.wustl.edu/oa_4/2900

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Journal of Hand Surgery Global Online 5 (2023) 744–750

Contents lists available at ScienceDirect

Journal of Hand Surgery Global Online

journal homepage: www.JHSGO.org

Original Research

Outcomes of Therapy and Ulnar Nerve Transposition for Elbow Stiffness After Pediatric Medial Epicondyle Fractures

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ARTICLE INFO

Article history:
Received for publication May 4, 2023
Accepted in revised form July 9, 2023
Available online August 12, 2023

Key words:
Elbow stiffness
Medial epicondyle fracture
Pediatric
Ulnar nerve

Purpose: Following medial epicondyle fractures, a subset of pediatric patients has persistent limitations in elbow motion. This study soughted to understand the patient characteristics of this group and to assess the effectiveness of intensive therapy and ulnar nerve transposition in improving elbow range of motion and patient-reported outcomes.
Methods: A cohort of 31 pediatric patients with stiffness after elbow trauma was narrowed to 8 pediatric patients (7 female) ranging in age from 9 to 14 years, who were diagnosed with medial epicondyle fractures and underwent intensive therapy and ulnar nerve transposition with or without elbow joint release. We collected demographic and objective data as well as subjective data including Patient-Reported Outcome Measurement Information System (PROMIS) scores before and after ulnar nerve transposition.
Results: Following initial intensive therapy, elbow range of motion improved by an average of 56°, and 7 of the 8 patients reached a functional motion arc of 100°. Subsequently, following ulnar nerve surgery with or without elbow release, motion improved by an average of 22°, and 5 of the 8 patients demonstrated improvement from this intervention. Surgery led to improvements in subjective outcomes with an improvement in PROMIS mobility scores by an average of 9 points, pain interference by 6 points, and upper extremity scores by 3 points. Based on a previously determined minimally important difference of three points, these indicate significant clinical improvements.
Conclusions: A subset of pediatric patients with persistent stiffness following medial epicondyle fractures may benefit from additional interventions, including intensive therapy, transposition of the ulnar nerve, and open capsular release. However, not all patients were improved after ulnar nerve surgery, and the identification and treatment of ulnar nerve irritability may not fully resolve preoperative symptoms in all patients.
Type of study/level of evidence: Therapeutic IV.

Medial epicondyle humerus fractures account for 11% to 20% of elbow fractures in the pediatric population, with a peak age of 11–12 years.[1–4] Up to 60% of these fractures are associated with elbow dislocation.[1,5] Management of medial epicondyle fractures remains controversial,[6] although nonsurgical management, consisting of immobilization in a long-arm cast with the elbow flexed at 90° for 4 weeks,[4,6–9] generally provides good results. Although several studies have shown equivalent or superior outcomes of nonsurgical compared with surgical treatment, surgical management has been associated with a higher rate of union when compared with nonsurgical management.[2,4,8–11] One systematic review demonstrated that surgery union rate odds were nine times higher than that with nonsurgical management.[4]

Various considerations have been indications for surgery. Agreement exists that open fractures and fractures involving incarcerated fragments are treated surgically.[2,4,10,12] Other potential indications lack agreement, including ulnar nerve dysfunction, dislocation, valgus instability, athletes who place increased demands on their upper extremities, and the amount of fracture

Declaration of interests: No benefits in any form have been received or will be received related directly to this article.

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https://doi.org/10.1016/j.jhsg.2023.07.002

displacement, warranting surgery.[3,5–7,9,13,14] Various outcome measures have been compared, including the rate of bony union, the presence of ulnar nerve symptoms, and functional outcomes as well as range of motion, activities of daily living, elbow strength, stability, and pain.[1–4] One particularly troubling outcome of medial epicondyle fractures is elbow stiffness, which may be related to the lack of bone union, heterotopic ossification, or damage to capsular ligaments and muscular structures.[6,15] The rate of elbow stiffness after medial epicondyle fractures ranges from 2.9% to 5.7%, but for those affected, the stiff elbow can be very limiting.[5,6,16]

In the subset of pediatric patients who have difficulty regaining full motion following a medial epicondyle fracture, daily activities may be affected. Although an elbow flexion-extension arc of 100° and forearm pronation-supination arc of 100° historically have been considered adequate to perform basic daily activities in adults, this is likely insufficient to meet the additional demands of technology for tasks, such as typing and cellphone use.[17,18] A recent study reported that in pediatric patients, the flexion arc required for contemporary tasks, such as holding a cell phone to the ear, texting, typing on a keyboard, and using a computer mouse was 40° to 148°.[19] In our experience, many patients are also unhappy with the aesthetics of the stiff elbow. This is especially true for those patients who participate in activities where form matters, such as cheerleading, gymnastics, and other performance arts.

Previous reports on the treatment of pediatric medial epicondyle fractures have typically concentrated on surgical techniques and fracture healing in surgically and nonsurgically treated patients. In this study, we assessed the characteristics and outcomes of pediatric patients experiencing elbow stiffness following medial epicondyle fractures. Our cohort underwent intensive therapy and ulnar nerve transposition, and we sought to evaluate patient demographics, injury characteristics, and both functional and patient-reported outcomes (PROs). We have found that ulnar nerve irritability in a young adolescent, typically girls, population may demonstrate findings of problematic medial elbow sensitivity and muscular cocontraction. We hypothesize that this represents underlying cubital tunnel syndrome, and in some patients, it is a contributing factor to elbow stiffness. We therefore believe that in patients with elbow stiffness who do not completely respond to focused therapy, surgery, including ulnar nerve transposition with or without elbow joint release is an effective adjunct in restoring a functional arc of motion.

Materials and Methods

The Washington University institutional review board approved this study as a retrospective investigation of a cohort of 8 pediatric patients (1 male and 7 female patients) with residual decreased elbow motion after initial surgical or nonsurgical treatment of medial epicondyle fractures who underwent ulnar nerve transposition with or without elbow joint release (Fig.1).

Patients presented at an average age of 12 years (range 9–14 years), between March 2015 and June 2020 (Table 1).

Our primary cohort was patients aged younger than 18 years who were treated for a medial epicondyle fracture; the focused patient group was identified by narrowing this group to those patients with clinical cubital tunnel syndrome treated with ulnar nerve surgery. Ulnar nerve irritability was assessed clinically, and all patients had a positive Tinel sign and a positive elbow flexion compression test. None of our patients had symptoms or clinical findings of numbness or tingling. Joint release was not always required because examination under anesthesia demonstrated full passive motion in some patients, whereas it was included as a part of the procedure for those patients with a rigid elbow contracture.

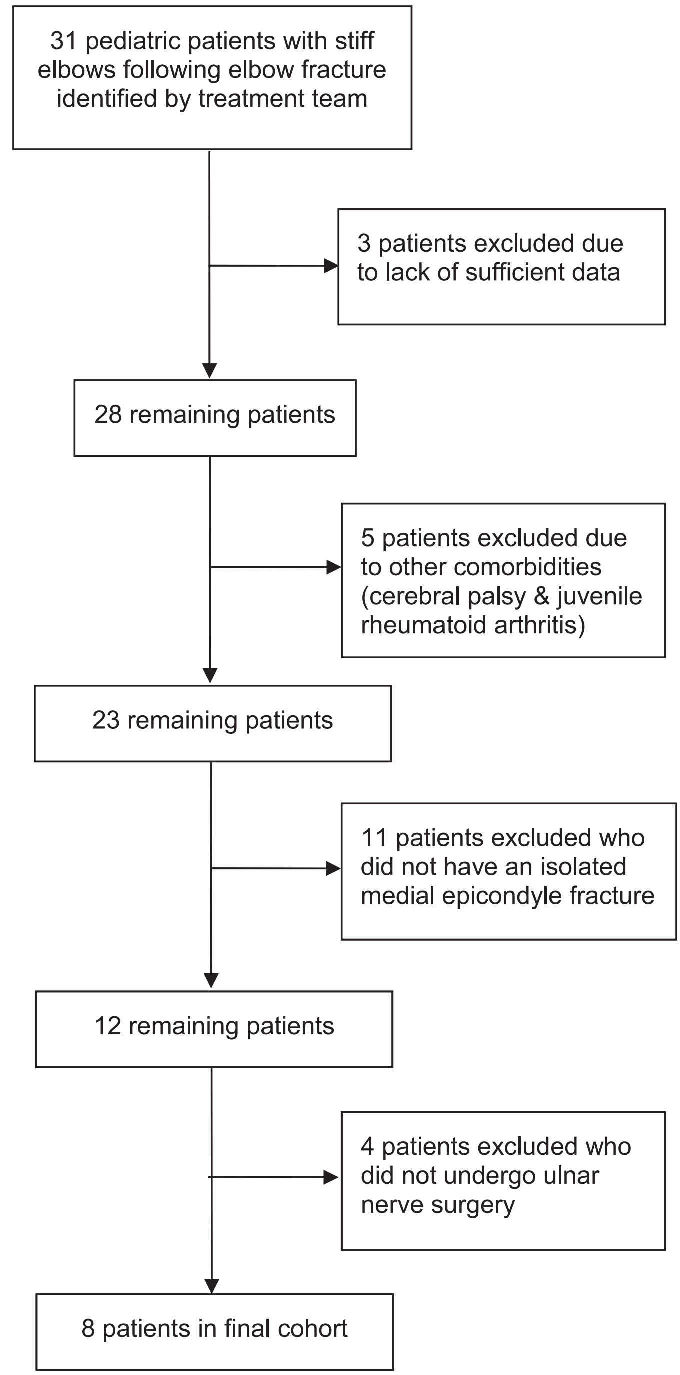

Figure 1. Cohort Selection. This figure outlines the cohort selection process. Patients who experienced trouble regaining motion after elbow fractures were first identified, and subsequently, patients were excluded because of the lack of available data and the presence of comorbidities, such as cerebral palsy and juvenile rheumatoid arthritis, that may affect normal movement and fracture healing. From this cohort, we focused on patients with medial epicondyle fractures; hence, patients with other fracture types or multiple fracture types were excluded. Finally, patients from this remaining group were excluded if they did not undergo ulnar nerve surgery.

The following data were collected from the medical records: age at injury, sex, mechanism of injury (gymnastics, cheerleading, wrestling, or fall while running), type of injury (including the presence or absence of a dislocation), and surgical course. We assessed additional variables, including time between the injury and the initial surgery, duration of initial immobilization, time from

Table 1
Demographics*

Patient No.	Age at Injury (y)	Sex	Injury Cause	Injury Type	Initial Management	Surgical Course
1	9	F	Gymnastics	Medial Epicondyle fracture/dislocation	Surgical	Surgery 1: ORIF for R medial epicondyle fracture Surgery 2: Removal of hardware, ulnar nerve transposition, and elbow joint release
2	10	F	Fall while running	Displaced Medial Epicondyle fracture and Radial Neck fracture	Surgical	Surgery 1: ORIF for L medial epicondyle and radial neck Surgery 2: Removal of hardware, ulnar nerve transposition, and elbow joint release
3	11	M	Wrestling	Medial Epicondyle fracture/dislocation	Nonsurgical	Surgery 1: ORIF for R medial epicondyle nonunion, ulnar nerve transposition, elbow joint release
4	12	F	Cheerleading	Medial Epicondyle isolated fracture	Nonsurgical	Surgery 1: ORIF for L medial epicondyle nonunion with distal radius bone graft, ulnar nerve transposition, and elbow joint release
5	12	F	Gymnastics	Medial Epicondyle isolated fracture	Nonsurgical	Surgery 1: ORIF for R medial epicondyle nonunion with distal radius bone graft Surgery 2: Removal of hardware, second distal radius bone graft, and ulnar nerve transposition
6	13	F	Gymnastics	Medial Epicondyle fracture/dislocation	Surgical	Surgery 1: ORIF for L medial epicondyle fracture Surgery 2: Removal of hardware, ulnar nerve transposition, and elbow joint release
7	13	F	Fall while running	Medial Epicondyle isolated fracture	Nonsurgical	Surgery 1: ORIF for L medial epicondyle nonunion with distal radius bone graft, ulnar nerve transposition, and elbow joint release Surgery 2: Elbow joint release
8	14	F	Gymnastics	Medial Epicondyle isolated fracture	Surgical	Surgery 1: ORIF for L medial epicondyle fracture Surgery 2: Ulnar nerve transposition
Average	12	—	—	—		

ORIF, open reduction internal fixation.
* This table represents the demographics of our cohort. This demonstrates that our cohort was predominantly women, and the most common injury mechanism was gymnastics. Patients were evenly split between initial surgical and nonsurgical management.

the injury to the start of therapy, and duration of therapy both before and after ulnar nerve surgery. We recorded changes in elbow extension and flexion at the start and end of the treatment period preceding ulnar nerve surgery, and we also compared changes before and after ulnar nerve surgery. The patient chart and therapy notes were examined for the presence of cocontraction during elbow flexion and extension.

We recorded Patient-Reported Outcome Measurement Information System (PROMIS) scores at two time points for each patient. These metrics were initially assessed directly before ulnar nerve surgery and again at the end of follow-up. In this cohort, the average time between initial and final scores was approximately 19 months (ranging from 2 months to 4.5 years). Patient-Reported Outcome Measurement Information System scores included mobility, pain interference, and upper extremity domains.[20] Patient-Reported Outcome Measurement Information System scores are normalized to have a mean value of 50, with a SD of 10 and a possible range of 0–100.[21] It is also important to note that each PROMIS score measures the amount of that item with 0 being the least amount and 100 being the most; for example, increased pain interference scores means worse pain. The minimally important difference in PROMIS scores is defined as the smallest difference that patients perceive to be meaningful, and in the pediatric population, this value has been previously determined to be three points.[22]

Therapy approach

Therapy in the pediatric and adolescent populations can be challenging. A multitude of techniques exist to regain motion; however, in our experience, progress is slower compared with adults, and aggressive therapy can be counterproductive. We educate the child and family on the difference between pain and stretch or motion. We also make sure the patient understands that we do not want her to experience sharp pain during treatment, and we allow the patient to control the initial motion. This helps to decrease fear and anticipation of pain during treatments. Cocontraction of elbow musculature (firing of the biceps and brachialis during attempted elbow extension and firing of the triceps during attempted elbow flexion) may exist in this population and will make the recovery of motion difficult. Children, perhaps somewhat differently than adults, often require a sense of control, and a clear explanation of the sensation of stretch versus pain is important.

Table 2
Therapy Course Promoting Motion Following Elbow Injury or Surgery*

Time/Key Therapy Steps	Therapy Goals and Interventions
Wk 0–6: Initial postoperative treatment and active movement	• Edema control and scar management (after surgery) • Postural assessment/correction • Active range of motion of elbow/forearm • Active assisted motion • Functional motion activities • Activities to increase reciprocal elbow motion
Wk 2–6: Additional activities as progress occurs	• Passive elbow motion • Contraction and relaxation of the elbow • Neuromuscular electrical stimulation • Joint mobilization • Home program provided
Wk 4–6: Night splint	• If no progress with extension, consider anterior night extension orthosis (window splint)
Wk 6: Day splint	• If motion remains limited, consider static progressive elbow flexion or extension daytime orthosis

* This table describes the therapy course used by our hand therapy team. For further details on the therapy approach, please see the Appendix (available online on the Journal's website at https://www.jhsgo.org).

Table 3
Length of Immobilization, Length of Therapy, and Range of Motion*

Patient No.	Time From Injury to First Surgery (d)	Length of Initial Immobilization (d)†	Time From Injury to Therapy Start (d)‡	Length of Therapy Before Ulnar Nerve Surgery (d)	Length of Therapy After Ulnar Nerve Surgery (d)	Elbow Extension/Flexion (ROM), Start of Initial Therapy Round	Elbow Extension/Flexion (ROM), End of Initial Therapy Round	Change in ROM During Initial Therapy Round
1	13	32	19	113	37	−48/90 (42)	−5/115 (110)	68
2	5	9	14	93	73	−25/110 (85)	2/144 (146)	61
3	465	39	45	219	345	−46/130 (84)	−3/135 (132)	48
4	557	43	61	73	125	−10/110 (100)	−25/145 (120)	20
5	612	26	47	56	70	−45/135 (90)	0/150 (150)	60
6	5	49	38	129	44	−15/85 (70)	−15/100 (85)	15
7	439	47	24	51	122	−42/105 (63)	−15/148 (133)	70
8	4	45	21	93	90	−40/85 (45)	10/140 (150)	105
Average	263	36	34	103	113	−34/106 (72)	−6/135 (128)	56

ROM, range of motion (degrees).
* This describes aspects of the treatment course for each patient, including time from injury to surgery (note that 4 of the 8 patients were initially treated nonsurgically), length of initial immobilization, time from injury to initial therapy, length of initial therapy and subsequent therapy, and elbow range of motion at the start and end of the initial therapy round.
† Immobilization time was considered to be time spent in a splint, cast, or hinged elbow brace, following the initial surgery or the initial injury if patients received initial nonsurgical management.
‡ Regardless of whether patients received surgical or nonsurgical initial management, the initial round of therapy usually began soon after the initial immobilization period.

Treatment consists of initial edema and scar management, followed by active motion progressing to passive motion, along with the addition of splints for stretch (Table 2).

Surgical approach

The final surgery in all patients in this series included subcutaneous ulnar nerve transposition. In the adolescent population and, particularly, in posttraumatic patients with ulnar nerve irritability, including a positive elbow flexion compression test, we transposed the ulnar nerve. We did not believe that decompression and neurolysis alone would address the nerve irritability including the tension component on the nerve. This was a heterogeneous group in this uncommon clinical scenario, and additional surgery was tailored to the patient's specific issues. Symptomatic nonunions were treated with revision screw fixation and bone grafting. Rigid joint contracture, as assessed in the operating room, was treated with open joint release.[23] This included release of the posterior medial collateral ligament in patients lacking full-elbow flexion and anterior capsulectomy in those lacking full-elbow extension.

Results

All patients in this cohort with medial epicondyle fractures had persistent decreased elbow motion and irritability of the ulnar nerve on direct assessment. In addition, all patients had evidence of cocontraction of the elbow musculature during their initial therapy period. Four patients (50%) were initially treated surgically (with open reduction internal fixation) for their medial epicondyle fracture, whereas the other four were initially treated nonsurgically (Table 1). All 8 patients underwent a period of immobilization after the fracture (consisting of a splint, cast, hinged elbow brace, or a combination) and then completed at least 8 weeks, and an average of 14 weeks, of regular therapy as described above and in the Appendix (available online on the Journal's website at https://www.jhsgo.org). Therapy improved elbow range of motion by an average of 56°, with notable improvement in both surgically and nonsurgically treated patients (Table 3).

Following this initial period of focused therapy, 7 of the 8 patients reached a classically defined functional arc of motion, defined as a 100° arc of extension/flexion.[17,18] However, the limitations in motion were limited to the patient, and in addition, each of the patients had irritability of the ulnar nerve. Subsequent ulnar nerve transposition, performed with elbow joint release in the setting of rigid elbow contracture, led to an average further increase in range of motion of 22°, with 5 of the 8 patients demonstrating improvement (Table 4).

No specific visible evidence of focal ulnar nerve pathology in any patient was found. Open anterior capsulectomy was performed from the medial approach before nerve transposition. Elbow motion in three patients did not improve following surgery. Two patients (patients 4 and 7) were initially treated nonsurgically with therapy and splinting; each developed elbow stiffness and both had a nonunion addressed at ulnar nerve surgery. In contrast, patient 6 was treated surgically for the fracture, and ulnar nerve surgery was performed 6 months later because of continued limitations in motion. She was lost to follow-up after approximately 2 months; hence, it is unknown whether sustained improvement exists.

We compared PROMIS scores just before ulnar nerve surgery and at the final available follow-up (mean 584 days, median 280 days between scores). Patient-Reported Outcome Measurement Information System mobility scores improved by an average of 9

Table 4
Ulnar Nerve Transposition Outcomes*

Patient No.	Number of Elbow Surgeries	Elbow Extension/ Flexion (ROM) Directly Prior to Ulnar Nerve Intervention	Elbow Extension/ Flexion (ROM) After Ulnar Nerve Surgery + Therapy	Change in ROM Following Ulnar Nerve Intervention + Therapy
1	2	0/115 (115)	3/140 (143)	28
2	2	−15/120 (105)	2/144 (146)	41
3	1	−35/120 (85)	−15/144 (129)	44
4	1	−20/140 (120)	−20/140 (120)	0
5	2	−25/135 (110)	−10/145 (135)	25
6	2	−10/90 (80)	−20/90 (70)	-10
7	2	−20/150 (130)	−10/140 (130)	0
8	2	−15/100 (85)	0/135 (135)	50
Average	2	−18/121 (104)	−9/135 (126)	22

* This table demonstrates the number of elbow surgeries each patient underwent, as well as the elbow range of motion (ROM) before and after the ulnar nerve intervention. Overall, ulnar nerve surgery increased elbow ROM by an average of 22°.

points, pain interference decreased by 6 points, and upper extremity scores improved by 3 points (Fig. 2). Based on the previously defined minimally important difference for pediatric patients of three points, these values are clinically significant.[22]

Discussion

A persistent decrease in elbow motion in children following medial epicondyle fractures may impair independence in activities of daily living. It can also limit participation in sports during a time when this involvement may be important to building self-esteem and promoting an active lifestyle. Patients with medial epicondyle fractures are at risk of developing ulnar nerve irritation or entrapment, as flexion of the elbow both tensions and brings the ulnar nerve in close proximity to the medial epicondyle.[24] Although rare, this complication has been well-documented in the literature.[25–32]

The role of ulnar nerve transposition remains ill-defined.[29,30] Previous case studies have noted that with this injury, the medial epicondyle fracture may be missed initially and becomes apparent later on when ulnar nerve symptoms emerge, including pain and stiffness.[26–28] Our study sought to better understand the characteristics of pediatric patients with decreased elbow motion following medial epicondyle fracture and responses to focused therapy and ulnar nerve transposition with or without elbow joint release, by assessing both functional and PROs. Ulnar nerve transposition was reserved for those patients who failed to improve sufficiently with therapy alone. Surgery led to meaningful motion gains and subjective improvement in some patients who experienced increased mobility, decreased pain, and increased upper extremity function based on reported PROMIS scores. However, not all patients improved after this surgery, and the identification and treatment of ulnar nerve irritability may not fully resolve the preoperative symptoms. Nonetheless, in our opinion, these findings suggest that awareness and treatment of ulnar nerve pathology in those persistently stiff patients with medial epicondyle fractures can lead to meaningful improvements for patients.

Causes of elbow stiffness can be divided into intrinsic, extrinsic, and mixed causes.[33] Intrinsic causes involve intra-articular phenomena, such as loose bodies or malunion, whereas extrinsic causes include capsular or muscular contracture, extra-articular malunions, and heterotopic bone formation.[33] One extrinsic cause of persistent elbow stiffness that is often addressed via hand therapy is cocontraction and guarding. We have found this more commonly in the pediatric population and specifically in the age group identified in this investigation, women with an average age of 12 years. Previous work using EMG has found that patients with elbow stiffness after injury display cocontraction of the biceps brachii during active elbow extension and during prolonged passive elbow extension, meaning patients show an equal magnitude of agonist and antagonist portions of this muscle.[34] Cocontraction may occur early, possibly because of fear and a lack of differentiation between pain and movement sensations, as this has been shown to act as a mechanism for joint stability.[35,36] Excessive coactivation can impair joint mobility, contributing to stiffness.[37] Cubital tunnel syndrome may contribute to this decreased motion as well, even without dramatic nerve findings. Compensation patterns may develop which allow the child to use their arm without moving the elbow fully, such as trunk substitution as well as shoulder and wrist motion.[38] This cocontraction is observed in a subset of patients early during active motion, and it continues during both active and passive motion. Although uncommon, this results in resistance to increased motion and can result in a rigid contracture of the elbow joint if not addressed early. Some therapeutic methods used in our clinic for joint cocontraction include contraction/relaxation with passive motion, cognitive distraction during treatment, Neuromuscular Electrical nerve Stimulation and Functional Electrical nerve Stimulation to agonistic muscles, mirror box therapy, vibration, pressure point release, and functional motion activities.

The average improvement in the extension/flexion elbow arc of our patients over the course of the initial round of therapy was 56°, improving from an average arc of 72° to 128°. After ulnar nerve transposition and subsequent therapy, the average improvement was 22°, from an average arc of 104° to 126°. The larger increase in motion gained from therapy likely relates to the fact that patients are initially stiffer, and ulnar nerve surgery is performed later after some improvements from therapy have been demonstrated. However, it is notable that several patients displayed decreased motion between the end of their initial therapy and their ulnar nerve surgery; hence, the gain in motion from the ulnar nerve intervention was not fully additive to the gains from therapy in this population with ulnar nerve irritability. This overall increased range of motion, nonetheless, represents a substantial improvement; for comparison, a recent study by Aldridge et al[39] assessing outcomes of patients aged 21 years and younger with elbow contractures who underwent anterior elbow release found an average elbow arc improvement of 37° (from 65° to 102°). Similarly, work by Andelman et al[40] on elbow contractures in patients aged 18 years and younger found an average improvement after arthroscopic release to be 35.2° (93° to 128°).

Several limitations to this study exist. First, as a retrospective investigation, our data are limited to what had been collected and documented in the medical record. None of the patients had nerve studies before surgery; the diagnosis was based purely on clinical examination. Furthermore, we feel comfortable with the previously collected data because a pediatric hand therapist collected all these data in a standardized fashion. A second limitation is that patients

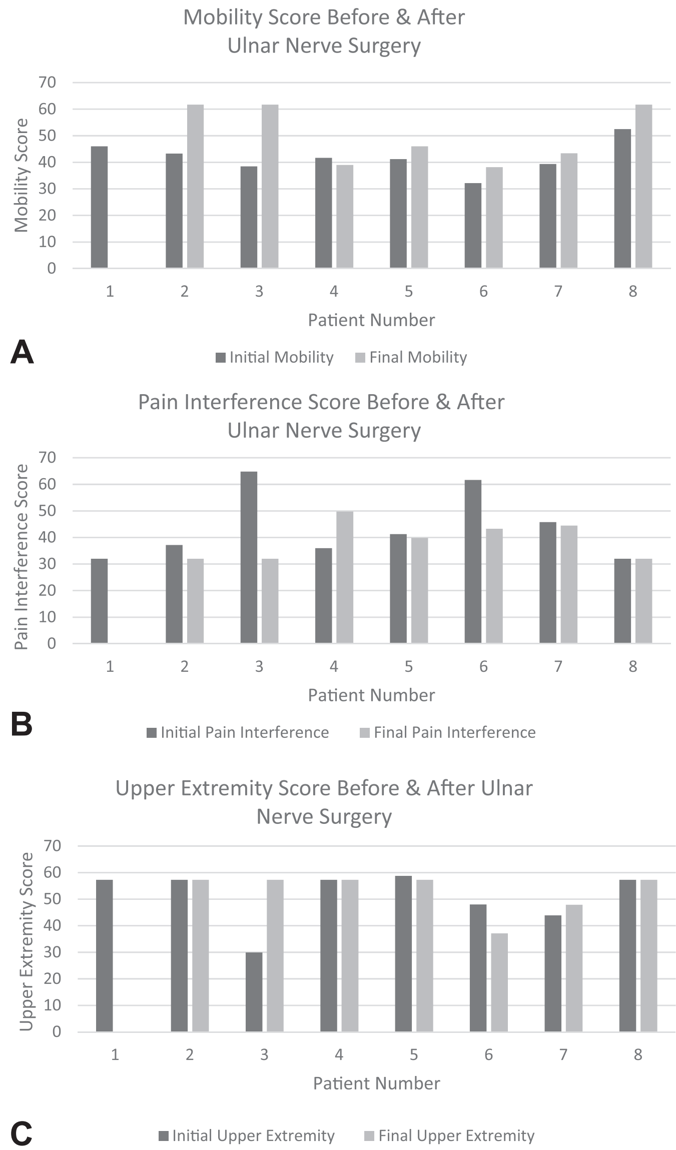

Figure 2. Changes in PROMIS scores before and after ulnar nerve surgery. This figure demonstrates the changes in PROMIS scores before and after ulnar nerve surgery. The initial PROMIS score was the last one recorded before surgery, and the final PROMIS score was the last one recorded at the end of follow-up. **A** Demonstrates that most patients reported increased subjective mobility scores. **B** Demonstrates that pain levels mostly remained the same or decreased following surgery, with one patient reporting an increase. **C** Demonstrates that upper extremity scores overall remained stable, with one patient reporting an increase and other reporting a decrease.

often underwent additional procedures beyond initial fracture fixation and subsequent ulnar nerve transposition. This is a common limitation in this patient population, and it makes it difficult to specify the benefit of any specific intervention. Fourth, patient adherence to therapy was variable. The success of therapy is heavily dependent on home repetition and parental involvement, and thus, the benefit from the same duration of therapy may differ depending on the patient and family motivation. Finally, this is a small cohort presenting with an uncommon issue of elbow stiffness after trauma; we are unable to compare results with a control group, and additional statistical analysis was not performed.

In summary, elbow stiffness after medial epicondyle fracture may be problematic in a subset of patients and is more common in participants in sports like gymnastics. We believe that ulnar nerve irritability can be identified on clinical examination and plays a role in cocontraction and decreased elbow motion in these patients. Our results demonstrate that some patients may benefit from transposition of the ulnar nerve and guided therapy; patients show an improved range of motion and meaningful change in PROs. However, our data are limited, and only one of the patients had an isolated ulnar nerve transposition, making it impossible to confirm that the transposition was the key to clinical improvement. Awareness of this potential issue and therapeutic approaches to address cocontraction and guarding are important components of treatment.

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