Minimal Epicondylectomy Improves Neurologic Deficits in Moderate to Severe Cubital Tunnel Syndrome

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Abstract

Background Previous studies of minimal medial epicondylectomy for cubital tunnel syndrome included patients with mild disease, making it difficult to determine how much this procedure improved sensory and motor impairments in patients with moderate to severe disease.

Questions/purposes We asked if minimal epicondylectomy improved sensory and motor impairments in patients with moderate to severe cubital tunnel syndrome.

Methods We retrospectively reviewed 25 patients treated with minimal medial epicondylectomy for advanced cubital tunnel syndrome involving motor weakness between January 2003 and February 2009. Preoperatively, five patients had Medical Research Council (MRC) Grade 4 motor strength without atrophy (McGowan Grade IIA), nine had MRC Grade 3 motor strength with detectable

atrophy (McGowan Grade IIB), and 11 had MRC Grade 3 or less motor strength with severe atrophy (McGowan Grade III). Postoperatively we obtained DASH scores and evaluated improvement of sensory impairment and motor impairment: excellent with minimal sensory deficit and motor deficit, good with mild deficits, fair with improved but persistent deficit(s), and poor with no improvement. The minimum followup was 13 months (mean, 46 months; range, 13–86 months).

Results The mean DASH score was 14 points (range, 2–47 points). Of the 25 patients, sensory improvement and motor improvement were excellent in 16 patients, good in five, fair in two, and poor in two. Twenty-three of the 25 patients improved at least one McGowan grade. There were no complications, such as medial elbow instability.

Conclusions Minimal medial epicondylectomy can improve sensory and motor impairments for patients with moderate to severe cubital tunnel syndrome.

Level of Evidence Level IV, therapeutic study. See the guidelines for authors for a complete description of levels of evidence.

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Each author certifies that his or her institution either has waived or does not require approval for the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.

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Introduction

Cubital tunnel syndrome is the second most common nerve compression neuropathy of the upper extremity after carpal tunnel syndrome [29]. Various surgical options for patients who do not respond to nonoperative treatment include simple decompression of the ulnar nerve around the elbow [1, 10, 25, 32], medial epicondylectomy [6, 11, 17, 19], or anterior transposition [15, 23]. Each method has advantages and disadvantages, although the choice generally is based on the surgeon's preference and experience [24, 30, 36].

Medial epicondylectomy decompresses the cubital tunnel and allows a minianterior transposition without excessive dissection and devascularization of the nerve [19]. However, conventional medial epicondylectomy may produce elbow instability, medial elbow pain, ulnar nerve subluxation, flexor-pronator weakness, and elbow flexion contracture [8]. To avoid these potential complications, some authors [16, 21] have advocated partial or minimal epicondylectomy. One study defined partial epicondylectomy as removal of greater than 40% of the medial epicondyle and minimal epicondylectomy as removal of less than 20% of the medial epicondyle [3]. Many studies using partial or minimal medial epicondylectomy have had 67% to 94% good to excellent results according to the Wilson and Krout criteria [43], in which excellent meant minimal sensory and motor deficits and no tenderness at the incision site, and good meant a mild deficit but occasional ache [4, 5, 8, 9, 18, 21, 28, 30, 37, 39]. However, in a cadaveric study, O'Driscoll et al. [34] suggested removing greater than 19% or 4 mm of the width of the medial epicondyle in the coronal plane damages the anterior medial collateral ligament. Therefore, minimal epicondylectomy might be a better option than conventional or partial medial epicondylectomy if it similarly affects symptom improvement with a lower risk of elbow instability. In the literature, surgical results (based on the Wilson-Krout criteria) of minimal epicondylectomy were reported as 79% to 94% good to excellent [4, 8, 9, 16, 18, 30, 37]. However, some authors noted the potential for selection bias in such studies, and suggested that although minimal epicondylectomy may be appropriate for mild cubital tunnel syndrome, anterior transposition may be more effective for moderate or severe grades of the disease [5, 29, 35, 44]. Most of the studies for minimal epicondylectomy [4, 9, 16, 18] included patients with mild disease, which makes it difficult to assess the effectiveness of the procedure for patients with advanced disease.

We therefore determined: (1) whether minimal epicondylectomy improved sensory impairment and motor impairment in patients with moderate to severe stages of cubital tunnel syndrome; (2) whether sensory improvement and motor improvement with minimal epicondylectomy for moderate or severe cubital tunnel syndrome were similar to those of other epicondylectomy or nerve transposition studies reported in the literature; (3) when patients recognized the subjective improvement of sensory function and motor function; and (4) whether complications occurred that were related to minimal epicondylectomy.

Patients and Methods

We retrospectively reviewed all 62 patients who underwent minimal medial epicondylectomy and in situ

decompression for treatment of cubital tunnel syndrome by one surgeon (GHB) between January 2003 and February 2009. All patients were confirmed as having cubital tunnel syndrome by physical examination and electrophysiologic diagnosis. Of these 62 patients, 54 had a minimum followup of 1 year. Of these 54, we excluded patients with the following conditions: (1) a double crush lesion, such as cervical radiculopathy, thoracic outlet syndrome, or Guyon's canal syndrome; (2) angular deformity of the elbow; (3) other medical conditions capable of causing a non-compressive neuropathy, such as diabetes mellitus, chronic renal failure, hypothyroidism, rheumatologic condition, or chronic alcohol abuse; (4) osteoarthritis or instability of the elbow; (5) workers compensation; (6) McGowan Grade I compression [17]; and (7) revision surgery for cubital tunnel syndrome. Patients with any other entrapment neuropathy that was not related to the ulnar nerve, such as carpal tunnel syndrome, were not excluded. We thus excluded 29 of the 54 patients: one with cervical radiculopathy, 11 with angular deformity of the elbow related to the fracture around elbow, six with diabetes mellitus, two with hypothyroidism, one with chronic renal failure, one with osteoarthritis, one with instability of the elbow, three with McGowan Grade I compression, and three who were lost to followup. The 29 exclusions left 25 patients available for study. There were 14 men and 11 women with a mean age of 53 years (range, 25–68 years). The mean BMI was 25 kg/m² (range, 21–32 kg/m²). The period from the onset of symptoms to surgery was 22 months (range, 2–120 months). The surgery was unilateral in 20 patients (seven right and 13 left elbows), and bilateral in five. In patients with bilateral surgery, we included and evaluated the side with the more severe disease grade. Twelve elbows were dominant side. Minimum followup was 12 months (mean, 46 months; range, 13–86 months). This retrospective study was approved by the Institutional Review Board of our hospital.

Preoperatively, all patients had routine physical examinations of the cervical spine and upper extremity, including four tests for thoracic outlet syndrome (Adson's test [2], hyperabduction test [31], military brace test [22], and Roos test [38]). In addition, we checked ROM of the elbow, clawing, Tinel's sign [42] over the ulnar nerve at the cubital tunnel, the elbow flexion test [33], local tenderness over the nerve, sensory deficit of the ulnar nerve-innervated territory by light touch, atrophy of the ulnar-innervated muscles, and grading of the intrinsic muscle strength. We did not check grip and pinch strength preoperatively. The average preoperative ROM of the elbow was 3° to 133°. Clawing was present in four patients, Tinel's sign in 20, local tenderness over the nerve in 21, and the elbow flexion test was positive in 19. We performed laboratory evaluations (blood glucose level,

erythrocyte sedimentation rate [ESR], c-reactive protein [CRP], rheumatoid factor [RF], thyroid stimulating hormone [TSH], blood urea nitrogen [BUN]/creatinine [Cr], glutamic oxaloacetic transaminase [GOT], glutamic pyruvic transaminase [GPT]) for every patient to rule out certain systemic conditions, such as diabetes mellitus, hypothyroidism, renal disease, rheumatologic condition, or chronic alcohol abuse, as these conditions could be possible causes of the noncompressive neuropathy. We performed nerve conduction studies and needle electromyography studies of the muscles innervated by the ulnar nerve in all patients. All had abnormal nerve conduction velocities of the ulnar nerve across the elbow on the affected side (mean, 32.7 ± 7.5 m/second). We noted signs of axonal degeneration (decreased amplitude, neurogenic recruitment, polyphasic potentials) in the ulnar-innervated muscle in 20 patients. Preoperative radiographs of the elbow included AP, lateral, and cubital tunnel view [41].

Two of us (KWK and HJL) preoperatively classified all patients according to a modification of the McGowan grading system reported by Goldberg et al. [17], in which the original McGowan Grade II [26] was subdivided based on the extent of motor compromise. We classified patients with symptoms without abnormal objective findings as having Grade I cubital tunnel syndrome. Grade IIA neuropathy was characterized by good intrinsic strength (MRC Grade 4 motor strength [27]) without detectable atrophy, and Grade IIB extremities had only fair intrinsic strength (MRC Grade 3) with intrinsic atrophy. We classified patients with neuropathy with intractable symptoms, profound motor weakness (MRC Grade 3 or less motor strength), severe intrinsic atrophy, and severe sensory disturbances as Grade III. Interobserver variability of the McGowan grade and Wilson-Krout criteria was tested using Cohen's kappa coefficient analysis using SPSS statistical software (version 17.0.1; SPSS Inc, Chicago, IL, USA). Cohen's kappa coefficients of interobserver variability of the McGowan grade and Wilson-Krout criteria were 0.89 ($p = 0.021$) and 0.91 ($p = 0.026$), respectively. Thus, grading taken by one of authors was used. Preoperatively, five patients had Grade IIA cubital tunnel syndrome, nine had Grade IIB, and 11 had Grade III. Each patient had a minimal medial epicondylectomy with in situ ulnar nerve decompression, as previously described [3], with preservation of the anterior medial collateral ligament.

One orthopaedic surgeon (GHB) performed all operations with the patient under general anesthesia. Under pneumatic tourniquet, the surgeon made a curved skin incision approximately 6 cm on the ulnar side of the elbow, parallel to the ulnar nerve and 1 cm behind the prominence of the medial epicondyle. During the subcutaneous dissection the medial antebrachial cutaneous nerve was identified and preserved. The surgeon identified the ulnar

nerve at its site of entrance to the cubital tunnel, and decompressed it from the arcade of Struthers to the flexor-pronator aponeurosis. Through a subperiosteal dissection, the medial epicondyle was exposed and 4 mm or less [34] of the tip of the epicondyle in the oblique coronal plane was removed to ensure anterior translation of the ulnar nerve at flexion (Fig. 1). The accurate translation length of nerve was not measured; however, the increased space for anterior translation of the nerve after osteotomy was recorded. After smoothing the raw bone surface with a rasp and rongeur, the periosteum was closed with absorbable sutures (Fig. 2). Full ROM of the elbow was tested to evaluate adequate decompression and to check that the ulnar nerve no longer was compressed against the medial epicondyle at the osteotomy site, especially in elbow flexion. The surgeon checked that there was no subluxation of the nerve and then released the tourniquet and performed hemostasis. The extent of the medial epicondylectomy during surgery was measured using a ruler; the thickness of the removed epicondyle was 4 mm or less (mean, 3.8 mm; range, 3.2–4.0 mm).

Fig. 1 A photograph shows how, through a subperiosteal dissection, the medial epicondyle (ME) was exposed and 4 mm or less of the tip of the epicondyle in the oblique coronal plane was removed using an osteotome.

Fig. 2 A photograph shows how, after smoothing the bony surface after osteotomy of the medial epicondyle (ME), the periosteum was closed with absorbable sutures.

A long arm splint was applied for 1 week with 90° elbow flexion. At that time the splint was discarded and the patient encouraged to move the elbow as tolerated without any physiotherapy.

Postoperatively, patients were seen for followups at 2 and 6 weeks, then at 3, 6, and 12 months, and then annually. For this study all patients visited the clinic, and one surgeon (GHB) evaluated all patients preoperatively and postoperatively. The postoperative evaluation was performed in the same manner as the preoperative evaluation, including the subjective symptoms, ROM of the elbow, clawing, Tinel's sign over the ulnar nerve at the cubital tunnel, sensory change of the ulnar nerve-innervated territory by light touch, atrophy of the ulnar-innervated muscles, and grading of the intrinsic muscle strength. We did not use two-point discrimination for sensory testing. We took grip and pinch strength measurements at each evaluation. Improvement in intrinsic muscle function was defined as increased strength measurement on physical examination or increased muscle mass [16]. At last followup we again assessed all patients clinically and graded them again according to the modified McGowan grading system. We asked patients to complete the DASH questionnaire. The DASH questionnaire is a patient-reported outcome measure that has been validated for use after elbow surgery [7, 20]. Two of us (KWK and HJL) graded all patients using the Wilson-Krout criteria [43]. Patients' results were graded as excellent with minimal sensory and motor deficits and no tenderness at the incision site, good with a mild deficit but occasional ache or tenderness at the incision or osteotomy site, fair with improved but persistent deficit, and poor with no improvement or a worsened condition or with complications such as elbow instability, medial elbow pain, ulnar nerve subluxation, flexor-pronator weakness, and elbow flexion contracture. We checked valgus instability of the elbow and assessed grip and key pinch strength (Baseline Hydraulic Hand Dynamometer; NexGen Ergonomics Inc, Quebec, Canada) by comparison with the opposite normal side only in the unilateral cases.

We evaluated the time of subjective improvement of the sensory disturbance and motor weakness by asking whether the patient had felt any improvement of the sensory and motor function at each visit to clinic.

Results

We observed improvement of at least one McGowan grade in 23 of the 25 patients (Table 1). In the five patients with Grade IIA lesions, three improved to complete motor and sensory functions, and the other two had improvement of lesions to Grade I. Of the nine patients with Grade IIB lesions, six improved to complete motor and sensory

functions, two improved to Grade I, but one had no improvement. In the 11 patients with Grade III lesions, five improved to complete motor and sensory functions, four improved to Grade I, one improved to Grade IIA, and one had no improvement. The mean DASH score was 14 points (range, 2–47 points). According to the Wilson-Krout criteria, the outcomes were excellent in 16 patients, good in five, fair in two, and poor in two. At final followup, grip and pinch strength were 88% and 91% of the opposite normal side with a correction for hand dominance, respectively. There was no change of postoperative ROM of the elbow compared with preoperative ROM. Clawing disappeared in two of the four patients with this condition.

Patients' subjective expression of improvement (whether the patient had felt any improvement) of sensory disturbance occurred at an average of 4.9 months (range, 0.5–13 months) after surgery, improvement of motor weakness at an average of 7.4 months (range, 1.5–24 months), and disappearance of tenderness at the osteotomy site at an average of 4.8 months (range, 1.5–12 months) postoperatively. Eighteen of 20 patients with atrophy of the ulnar-innervated muscles before surgery had improvement of intrinsic muscle function.

Substantial tenderness at the osteotomy site was present in two elbows at last followup. We identified no patients with medial elbow instability and ulnar nerve subluxation and none with symptoms or signs related to the medial antebrachial cutaneous nerve injury.

Discussion

Various surgical options for patients with cubital tunnel syndrome have been reported. Simple decompression of the ulnar nerve around the elbow [1, 10, 25, 32], medial epicondylectomy [6, 11, 17, 19], or anterior transposition [15, 23] have advantages and disadvantages. Thus the choice generally is based on the surgeon's preference and experience [24, 30, 36]. Medial epicondylectomy has the advantages of decompression of the nerve without excessive dissection and devascularization of the nerve [19]. However, conventional medial epicondylectomy may result in elbow instability, medial elbow pain, ulnar nerve subluxation, flexor-pronator weakness, and elbow flexion contracture [8]. Partial and minimal epicondylectomy have been used to avoid these potential complications, and satisfactory functional improvements regardless of the disease stage have been reported [4, 5, 8, 9, 18, 21, 28, 30, 37, 39]. Partial epicondylectomy has been defined as removal of greater than 40% of the medial epicondyle and minimal epicondylectomy has been defined as removal of less than 20% of the medial epicondyle [3]. However, some authors pointed out a potential selection bias: patients with less

severe symptoms were treated more frequently with epicondylectomy, whereas patients with higher-grade compression syndromes were treated more often with transposition [29]. Thus the purpose of this study was to determine: (1) whether minimal epicondylectomy improved sensory impairment and motor impairment in patients with moderate to severe stages of cubital tunnel syndrome; (2) whether sensory improvement and motor improvement after minimal epicondylectomy for moderate or severe cubital tunnel syndrome were similar to those of other studies of epicondylectomy or nerve transposition reported in the literature; (3) when patients recognized the subjective improvement of sensory function and motor function; and (4) whether complications occurred that were related to the minimal epicondylectomy.

There were a few limitations to this study. First, we had no comparative groups that underwent a different surgical treatment. We therefore compared our data with previously reported data. Published studies used only unvalidated instruments, therefore we added DASH scores as the

validated postoperative evaluation and used categorical variables for convenience for comparison with the other studies. Categorical variables, however, are prone to interobserver variability and may not have agreed with patient assessments. Second, although our data suggested minimal medial epicondylectomy with in situ decompression for patients with moderate to severe grades of cubital tunnel syndrome could be as effective as for those with mild disease, it remains controversial whether medial epicondylectomy has an additional role above and beyond in situ release [24, 28, 36, 39]. However, an important role of minimal epicondylectomy is that it can provide mini-anterior nerve translation not obtained by in situ release. Anterior transposition of the ulnar nerve also is a combination of in situ release and anterior nerve translation. Additionally, our focus was whether minimal epicondylectomy with in situ decompression produced a similar outcome for those with moderate to severe grades of cubital tunnel syndrome compared with the mild grades of disease. A properly powered prospective study could be

Table 1. Patient data

Patient	Age (years)	Duration of symptoms (months)	Followup (months)	Axonal degeneration	Preoperative McGowan grade	Onset of improvement (months)			Final McGowan grade	Wilson and Krout grade
						Sensory disturbance	Motor weakness	Osteotomy site pain		
1	52	12	41	+	IIB	3	3	3	I	Good
2	29	2	42	—	IIA	3	3	3	Normal	Excellent
3	65	60	78	+	III	6	3	6	I	Fair
4	47	3	44	+	IIB	3	6	6	Normal	Excellent
5	51	8	52	+	III	6	6	6	I	Good
6	68	12	23	+	III	12	6	6	III	Poor
7	60	2	54	+	III	12	12	12	IIA	Fair
8	56	18	51	+	III	6	6	3	Normal	Excellent
9	25	60	13	—	IIA	3	3	6	Normal	Excellent
10	68	3	42	+	IIB	6	24	6	Normal	Excellent
11	64	120	42	+	IIB	0.5	6	6	Normal	Excellent
12	46	12	58	+	III	6	6	3	I	Good
13	62	72	59	+	IIB	3	6	6	Normal	Excellent
14	58	9	59	+	IIB	6	6	6	I	Excellent
15	51	8	59	+	III	3	6	3	Normal	Excellent
16	52	24	38	+	III	1.5	1.5	1.5	Normal	Excellent
17	55	6	84	+	IIB	6	12	3	Normal	Excellent
18	60	8	29	+	III	1.5	1.5	1.5	I	Good
19	59	7	14	+	IIB	13	13	6	IIB	Poor
20	52	60	86	+	III	3	3	3	Normal	Excellent
21	60	9	14	—	IIA	3	12	6	I	Good
22	47	7	83	+	IIB	1.5	1.5	1.5	Normal	Excellent
23	32	6	26	+	III	3	1.5	3	Normal	Excellent
24	50	5	28	—	IIA	6	12	12	Normal	Excellent
25	54	24	31	—	IIA	6	24	1.5	I	Excellent

Table 2. Literature review of outcomes of partial and minimal medial epicondylectomy for cubital tunnel syndrome

Study	Type of medial epicondylectomy	Total number of cases	Mean followup (months)	Grading system	Preoperative		Postoperative		Complications
					Grade	Number of cases	Grade	Number of cases	
Kaempffe & Farbach [21]	Partial	27	13 (3–25)	McGowan	I	1	I	14	44% medial elbow pain; no valgus instability; 11% grip strength loss, 10% pinch strength loss; 15% flexion contracture (> 10°); 4% delayed wound healing.
					II	20	II	11	
					III	6	III	2	
Muermans and De Smet [30]	Partial	60	38.8 (6–88)	McGowan	I	8	Normal	23	35% medial elbow pain; 2% valgus instability; 13% ulnar nerve subluxation; 15.7% grip strength loss, 14% pinch strength loss; 13% flexion contracture (> 10°); 2% brachial plexus injury; 2% Reflex sympathetic dystrophy; 7% MABC injury.
					IIA	24	I	21	
					IIB	16	IIA	12	
					III	12	IIB	0	
Popa and Dubert [37]	Partial	55	38 (4–97)	McGowan	I	25	Normal	41	13% medial elbow pain; no valgus instability; no ulnar nerve subluxation; no weakness of flexors; 2% flexion contracture.
					II	12	I	5	
					III	18	II	3	
							III	6	
Efsthathopoulos et al. [8]	Partial	80	32 (26–50)	McGowan	I	16	Normal	42	16% medial elbow pain; no valgus instability; no ulnar nerve subluxation; 23% grip strength loss, 10% pinch strength loss; no flexion contracture.
					II	40	I	11	
					III	24	II	19	
							III	8	
Mitsionis et al. [28]	Partial	45	37 (24–120)	McGowan	I	0	Normal	NA	4% medial elbow pain; no valgus instability; no ulnar nerve subluxation; 17% grip strength loss, 9% pinch strength loss; no flexion contracture.
					IIA	18	I	NA	
					IIB	15	IIA	NA	
					III	12	IIB	NA	
Schnabl et al. [39]	Partial	29	41.4 (14.6–73.7)	NA			III	NA	48% medial elbow pain; no valgus instability; 9% grip strength loss, 16.2% pinch strength loss; no flexion contracture.
Göbel et al. [16]	Minimal	66	27 (14–72)	McGowan	I	10	Normal	NA	52% medial elbow pain; no valgus instability; no ulnar nerve subluxation; no flexor pronator weakness; 2% flexion contracture (> 5°); 2% superficial wound infection.
					II	44	I	NA	
					III	12	II	NA	
							III	4	
Erol et al. [9]	Minimal	17	32 (25–64)	McGowan	I	3	Normal	NA	24% medial elbow pain; no valgus instability; no ulnar nerve subluxation; no flexor pronator weakness; no flexion contracture.
					II	11	I	NA	
					III	1	II	NA	
							III	NA	

Table 2. continued

Study	Type of medial epicondylectomy	Total number of cases	Mean followup (months)	Grading system	Preoperative		Postoperative		Complications
					Grade	Number of cases	Grade	Number of cases	
Baek et al. [4]	Minimal	22	24 (12–40)	McGowan	I	4	Normal	NA	No medial elbow pain; no valgus instability; no MABC injury.
					IIA	9	I	3	
					IIB	3	IIA	2	
					III	6	IIB	NA	
Hahn et al. [18]	Minimal	29	31.2 (24–39)	Dellon	I	2	Normal	NA	No medial elbow pain; no valgus instability; no ulnar nerve subluxation; no flexor pronator weakness.
					II	15	I	NA	
					III	12	II	NA	
							III	1	
Current study	Minimal	25	46.0 (13–86)	McGowan	I	NA	Normal	14	8% medial elbow pain; no valgus instability; no ulnar nerve subluxation; 11.6% grip strength loss, 9% pinch strength loss; no flexion contracture; no MABC injury.
					IIA	5	I	8	
					IIB	9	IIA	1	
					III	11	IIB	1	
							III	1	

NA = not available; MABC = medial antebrachial cutaneous nerve.

helpful in establishing whether medial epicondylectomy has a place in the treatment of cubital tunnel syndrome.

The mean postoperative DASH score for our patients was 14 points (range, 2–47 points), suggesting minor limitations in the activities of daily living. Minimal epicondylectomy with in situ decompression improved at least one McGowan grade in 23 of 25 (92%) patients with moderate to severe cubital tunnel syndrome, with 21 of 25 (84%) having good to excellent results according to the Wilson-Krout criteria. A few studies reported similar outcomes (according to the Wilson-Krout criteria) for minimal epicondylectomy for cubital tunnel syndrome [4, 9, 16, 18] (Table 2). Published studies have shown subjective improvement was 79% good to excellent results in 66 patients [16], 94% good to excellent results in 17 elbows [9], an overall improvement of 95% (86% good to excellent results) in 22 patients [4], and 73% good to excellent results in 29 patients [18]. Two of our patients had poor results although we could find no specific reason. In most cases, the final evaluations were performed after more than 24 months followup (as much as 59 or 84 months). However, followups of the two patients with poor results were relatively short (14 and 23 months); therefore, we think it is possible there would be some additional improvement with longer followup.

Our observations suggest minimal epicondylectomy produced similar surgical outcomes (according to the Wilson-Krout criteria) for moderate to severe disease as partial or total epicondylectomy and anterior transposition. For partial epicondylectomy, improvement percentages have been reported as 67% good to excellent results in 27 patients [21], 75% good to excellent results in 60 patients [30], 75% good to excellent results in 55 patients [37], 79% good to excellent results in 80 patients [8], and 80% good to excellent results in 45 patients [28]. Several studies have shown that after total epicondylectomy, patients experienced an overall subjective improvement of approximately 90% [9, 14, 16, 25, 40]. In studies of anterior transposition of ulnar nerve in patients with severe-stage cubital tunnel syndrome, the improvement percentages were reported as 72% to 100% [12, 13, 15, 23].

In our study, the patients' recognition of sensory improvement occurred at a mean followup of 4.9 months, motor recovery at 7.4 months, and disappearance of substantial tenderness at the osteotomy site at 4.8 months. These findings concurred with those in previous studies [8, 9, 16], even though there were limited studies showing the time of subjective improvement after minimal epicondylectomy. One study noted sensory disturbances disappeared in 87% of the patients by 3 months postoperatively, and osteotomy-related discomfort during elbow flexion was abated after a mean of 30 days [8]. In one study, residual

medial elbow pain was reported as 52% at 6 months and 30% 1 year [16]. In another study, the authors reported tenderness at the osteotomy site disappeared after a mean of 3 months in 23.5% patients [9].

There are potential complications after medial epicondylectomy, such as valgus instability of the elbow, medial elbow pain, ulnar nerve subluxation, flexor-pronator weakness, elbow flexion contracture, and loss of grip strength [8]. In previous studies of partial or minimal medial epicondylectomy, complication rates were reported to range from 0% to 52% for medial elbow pain [4, 8, 9, 16, 18, 21, 28, 30, 37, 39], 0% to 2% for valgus instability [4, 8, 9, 16, 18, 21, 28, 30, 37, 39], 11% to 23% for grip strength loss [8, 21, 28, 30, 39], 0% to 15% for flexion contracture [8, 9, 16, 21, 28, 30, 37, 39], and 2% to 4% for superficial wound problems [16, 21]. We identified no patients with serious complications, although two patients had mild tenderness at the osteotomy site.

A minimal medial epicondylectomy with in situ decompression can improve sensory impairment and motor impairment with a low complication rate in patients with moderate to severe cubital tunnel syndrome.

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References

- Adelaar RS, Foster WC, McDowell C. The treatment of the cubital tunnel syndrome. *J Hand Surg Am.* 1984;9:90–95.
- Adson AW. Cervical ribs: symptoms, differential diagnosis and indications for section of the insertion of the scalenus anticus muscle. *J Int Coll Surg.* 1951;16:546–559.
- Amako M, Nemoto K, Kawaguchi M, Kato N, Arino H, Fujikawa K. Comparison between partial and minimal medial epicondylectomy combined with decompression for the treatment of cubital tunnel syndrome. *J Hand Surg Am.* 2000;25:1043–1050.
- Baek GH, Kwon BC, Chung MS. Comparative study between minimal medial epicondylectomy and anterior subcutaneous transposition of the ulnar nerve for cubital tunnel syndrome. *J ShoulderElbow Surg.* 2006;15:609–613.
- Chung KC. Treatment of ulnar nerve compression at the elbow. *J Hand Surg Am.* 2008;33:1625–1627.
- Craven PR Jr, Green DP. Cubital tunnel syndrome: treatment by medial epicondylectomy. *J Bone Joint Surg Am.* 1980;62:986–989.
- Dawson J, Doll H, Boller I, Fitzpatrick R, Little C, Rees J, Jenkinson C, Carr AJ. The development and validation of a patient-reported questionnaire to assess outcomes of elbow surgery. *J Bone Joint Surg Br.* 2008;90:466–473.
- Efstathiopoulos DG, Themistocleous GS, Papagelopoulos PJ, Chloros GD, Gerostathopoulos NE, Soucacos PN. Outcome of partial medial epicondylectomy for cubital tunnel syndrome. *Clin Orthop Relat Res.* 2006;444:134–139.
- Erol B, Tetik C, Sirin E. [The mid-term results of minimal medial epicondylectomy and decompression for cubital tunnel syndrome] [in Turkish]. *Acta Orthop Traumatol Turc.* 2004;38:330–336.

10. Folberg CR, Weiss AP, Akelman E. Cubital tunnel syndrome. Part II: treatment. *Orthop Rev.* 1994;23:233–241.
11. Froimson AI, Anouchi YS, Seitz WH Jr, Winsberg DD. Ulnar nerve decompression with medial epicondylectomy for neuropathy at the elbow. *Clin Orthop Relat Res.* 1991;265:200–206.
12. Gervasio O, Gambardella G. Anterior submuscular transposition of the ulnar nerve in severe cubital tunnel syndrome: personal experience. *J Neurosurg Sci.* 2004;48:113–116.
13. Gervasio O, Gambardella G, Zacccone C, Branca D. Simple decompression versus anterior submuscular transposition of the ulnar nerve in severe cubital tunnel syndrome: a prospective randomized study. *Neurosurgery.* 2005;56:108–117; discussion 117.
14. Geutjens GG, Langstaff RJ, Smith NJ, Jefferson D, Howell CJ, Barton NJ. Medial epicondylectomy or ulnar-nerve transposition for ulnar neuropathy at the elbow? *J Bone Joint Surg Br.* 1996;78:777–779.
15. Glowacki KA, Weiss AP. Anterior intramuscular transposition of the ulnar nerve for cubital tunnel syndrome. *J Shoulder Elbow Surg.* 1997;6:89–96.
16. Göbel F, Musgrave DS, Vardakas DG, Vogt MT, Sotereanos DG. Minimal medial epicondylectomy and decompression for cubital tunnel syndrome. *Clin Orthop Relat Res.* 2001;393:228–236.
17. Goldberg BJ, Light TR, Blair SJ. Ulnar neuropathy at the elbow: results of medial epicondylectomy. *J Hand Surg Am.* 1989;14:182–188.
18. Hahn SB, Choi YR, Kang HJ, Kang ES. Decompression of the ulnar nerve and minimal medial epicondylectomy with a small incision for cubital tunnel syndrome: comparison with anterior subcutaneous transposition of the nerve. *J Plast Reconstr Aesthet Surg.* 2010;63:1150–1155.
19. Heithoff SJ, Millender LH, Nalebuff EA, Petruska AJ Jr. Medial epicondylectomy for the treatment of ulnar nerve compression at the elbow. *J Hand Surg Am.* 1990;15:22–29.
20. Hudak PL, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand) [corrected]. The Upper Extremity Collaborative Group (UECG). *Am J Ind Med.* 1996;29:602–608.
21. Kaempffe FA, Farbach J. A modified surgical procedure for cubital tunnel syndrome: partial medial epicondylectomy. *J Hand Surg Am.* 1998;23:492–499.
22. Lain TM. The military brace syndrome: a report of sixteen cases of Erb's palsy occurring in military cadets. *J Bone Joint Surg Am.* 1969;51:557–560.
23. Lascar T, Lulan J. Cubital tunnel syndrome: a retrospective review of 53 anterior subcutaneous transpositions. *J Hand Surg Br.* 2000;25:453–456.
24. Macadam SA, Bezuhly M, Lefavre KA. Outcomes measures used to assess results after surgery for cubital tunnel syndrome: a systematic review of the literature. *J Hand Surg Am.* 2009;34:1482–1491.e5.
25. Manske PR, Johnston R, Pruitt DL, Strecker WB. Ulnar nerve decompression at the cubital tunnel. *Clin Orthop Relat Res.* 1992;274:231–237.
26. McGowan AJ. The results of transposition of the ulnar nerve for traumatic ulnar neuritis. *J Bone Joint Surg Br.* 1950;32:293–301.
27. Medical Research Council. *Aids to the Examination of the Peripheral Nervous System.* London, England: Her Majesty's Stationery Office; 1976.
28. Mitsionis GI, Manoudis GN, Paschos NK, Korompilias AV, Beris AE. Comparative study of surgical treatment of ulnar nerve compression at the elbow. *J Shoulder Elbow Surg.* 2010;19:513–519.
29. Mowlavi A, Andrews K, Lille S, Verhulst S, Zook EG, Milner S. The management of cubital tunnel syndrome: a meta-analysis of clinical studies. *Plast Reconstr Surg.* 2000;106:327–334.
30. Muermans S, De Smet L. Partial medial epicondylectomy for cubital tunnel syndrome: outcome and complications. *J Shoulder Elbow Surg.* 2002;11:248–252.
31. Mulder DS, Greenwood FA, Brooks CE. Posttraumatic thoracic outlet syndrome. *J Trauma.* 1973;13:706–715.
32. Nathan PA, Myers LD, Keniston RC, Meadows KD. Simple decompression of the ulnar nerve: an alternative to anterior transposition. *J Hand Surg Br.* 1992;17:251–254.
33. Novak CB, Lee GW, Mackinnon SE, Lay L. Provocative testing for cubital tunnel syndrome. *J Hand Surg Am.* 1994;19:817–820.
34. O'Driscoll SW, Jalszynski R, Morrey BF, An KN. Origin of the medial ulnar collateral ligament. *J Hand Surg Am.* 1992;17:164–168.
35. Osterman AL, Spiess AM. Medial epicondylectomy. *Hand Clin.* 2007;23:329–337, vi.
36. Palmer BA, Hughes TB. Cubital tunnel syndrome. *J Hand Surg Am.* 2010;35:153–163.
37. Popa M, Dubert T. Treatment of cubital tunnel syndrome by frontal partial medial epicondylectomy: a retrospective series of 55 cases. *J Hand Surg Br.* 2004;29:563–567.
38. Roos DB. Thoracic outlet syndrome is underdiagnosed. *Muscle Nerve.* 1999;22:126–129; discussion 137–138.
39. Schnabl SM, Kisslinger F, Schramm A, Dragu A, Kneser U, Unglaub F, Horch RE. Objective outcome of partial medial epicondylectomy in cubital tunnel syndrome. *Arch Orthop Trauma Surg.* 2010;130:1549–1556.
40. Seradge H, Owen W. Cubital tunnel release with medial epicondylectomy factors influencing the outcome. *J Hand Surg Am.* 1998;23:483–491.
41. Thomsen PB. Compression neuritis of the ulnar nerve treated with simple decompression. *Acta Orthop Scand.* 1977;48:164–167.
42. Tinel J. “Tingling” signs with peripheral nerve injuries. 1915. *J Hand Surg Br.* 2005;30:87–89.
43. Wilson DH, Krout R. Surgery of ulnar neuropathy at the elbow: 16 cases treated by decompression without transposition. Technical note. *J Neurosurg.* 1973;38:780–785.
44. Zlowodzki M, Chan S, Bhandari M, Kalliaainen L, Schubert W. Anterior transposition compared with simple decompression for treatment of cubital tunnel syndrome: a meta-analysis of randomized, controlled trials. *J Bone Joint Surg Am.* 2007;89:2591–2598.