Orthopaedics & Traumatology: Surgery & Research 105 (2019) 867–876

Contents lists available at ScienceDirect

Orthopaedics & Traumatology: Surgery & Research

journal homepage: www.elsevier.com

Review article

Revision surgery for refractory cubital tunnel syndrome: A systematic review

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ARTICLE INFO

Article history:
Received 8 January 2019
Accepted 27 March 2019

Keywords:
Revision surgery
Refractory
Cubital tunnel syndrome
Systematic review

ABSTRACT

Background: Indications for revision surgery are unclear in refractory cubital tunnel syndrome patients, and the optimal surgical method has not been determined. The systematic review evaluates the evidence of functional outcome for revision surgery in refractory cubital tunnel syndrome patients.
Hypothesis: We hypothesize that functional outcome of revision surgery in refractory cubital tunnel syndrome will be favorable.
Methods: We searched PubMed, Ovid/MEDLINE, Cochrane, Google Scholar, and EMBASE databases using the keywords "cubital tunnel syndrome" or "recurrent cubital tunnel syndrome" and "revision surgery" according to the MeSH index for English-language studies. We performed a systematic review using PRISMA guidelines. The review was registered in PROSPERO (CRD42018096622).
Results: Based on the Oxford Centre for Evidence-Based Medicine criteria, one level 3b study and nine level 4 studies were identified, including 195 elbows of 192 patients aged 15–75 years. The remission period for recurrent cubital tunnel syndrome was 6–21 months, and the follow-up period was 6–113 months. Transposition surgery was the primary surgery in 99 (51%) of 178 elbows. The most common intraoperative finding at revision surgery was perineural scarring (79%), with the most frequent entrapment site being the medial intermuscular septum (33%). The most common revision surgery was submuscular transposition of the ulnar nerve (75%). Most studies reported favorable outcomes, although outcomes varied widely among studies.
Conclusion: This is the first study to summarize the functional outcomes of revision surgery for refractory cubital tunnel syndrome which showed to be favorable. Functional outcomes were averagely reported and varied widely. A consensus regarding the functional outcomes parameter after surgery for cubital tunnel syndrome is urgently needed.
Level of evidence: III, systematic review.

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https://doi.org/10.1016/j.otsr.2019.03.020
1877-0568/

1. Introduction

Compressive neuropathy of the ulnar nerve at the elbow, known as cubital tunnel syndrome, is the second most common type of compressive neuropathy in the upper extremities, surpassed only by carpal tunnel syndrome [1] The clinical manifestations of compressive ulnar neuropathy include pain, paresthesia of the fourth and fifth fingers, and weakness or atrophy of the intrinsic hand muscles. Multiple sites of compression are present around the elbow joint, including the following: (1) the arcade of Struthers, (2) the medial intermuscular septum, (3) the medial epicondyle, (4) the cubital tunnel, (5) the arcade of Osborne, and (6) aponeurosis between the flexor carpi ulnaris and the flexor digitorum superficialis.

The conservative treatment of the cubital tunnel syndrome include avoidance of factors provoking symptoms, night splint application and nerve gliding or mobilization [2]. Surgical treatment is indicated when conservative treatment fails to relieve symptoms. Although the first surgical treatment for cubital tunnel syndrome was reported > 100 years ago, the optimal surgical technique remains unclear. Surgical techniques for treating refractory cubital tunnel syndrome include the following: (1) in situ decompression and (2) anterior ulnar nerve transposition and medial epicondylectomy. Although surgical intervention is generally associated with favorable outcomes, surgical failure has been reported in 10%–25% of patients [3,4]. A review literature of 50 studies found that nearly 75% of patients reported recurrence [5]. The types of failure following decompression surgery have included incomplete decompression and secondary compression due to primary surgical scars and new compression [5,6]. Regardless of their cause, persistent or recurrent symptom can lead to revision surgery, but the type of primary surgery resulting in a minimal need for revision surgery remains unclear. Furthermore, to our knowledge, no consensus exists regarding the optimal method of revision surgery for failed cubital tunnel syndrome.

The primary objective of current systematic review was to define the functional outcome of revision surgery in patients with refractory cubital tunnel syndrome. Secondary objectives were to define (1) the types of primary and revision surgeries and (2) intraoperative findings and pathology level in patients undergoing revision surgery. We hypothesize that functional outcome of revision surgery in refractory cubital tunnel syndrome will be favorable.

2. Materials and methods

2.1. Search strategy

This systematic review was registered in PROSPERO (registration no: CRD42018096622) and performed according to Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines [7]. The PubMed, Ovid/MEDLINE, Cochrane, Google Scholar, and EMBASE databases were searched electronically using keywords chosen according to Medical

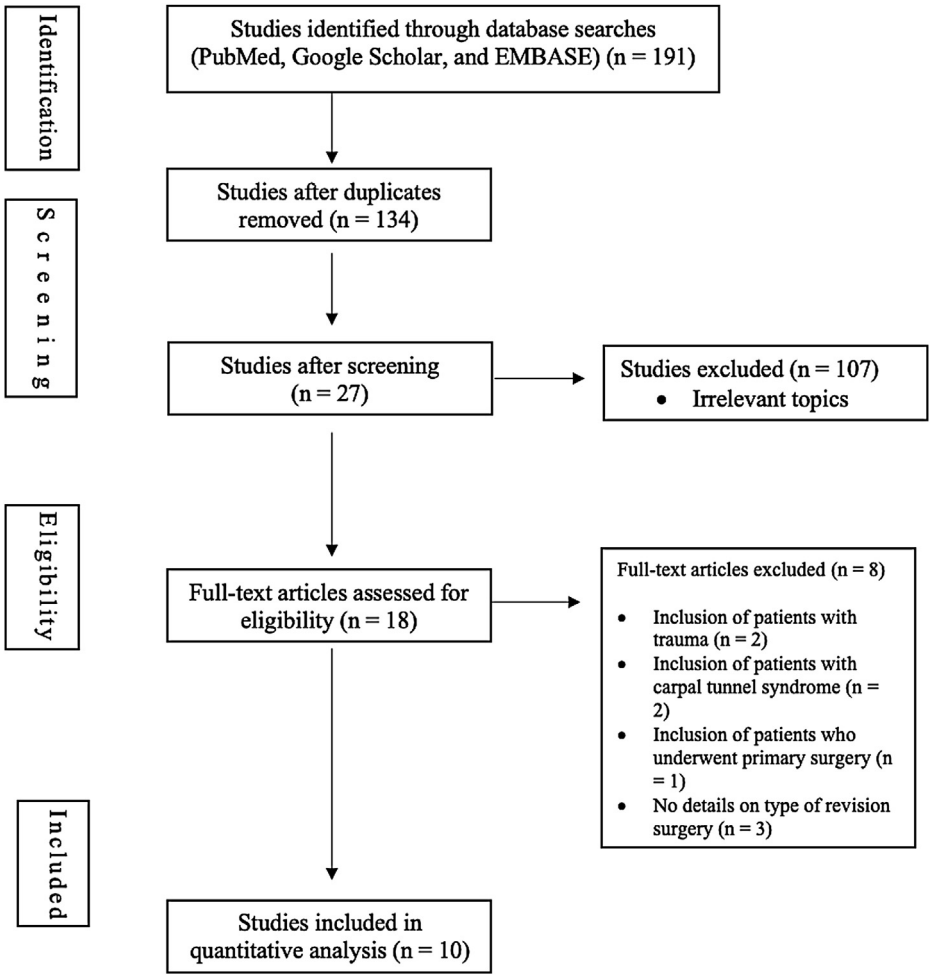

Fig. 1. Flowchart of article selection through different phases of systematic review.

Subject Headings (MeSH) and All Fields index, including the keywords "cubital tunnel syndrome" (MeSH terms) or "recurrent cubital tunnel syndrome" (all Fields) and "revision surgery" (all Fields). The number of studies was limited; thus, there were no restrictions regarding patient demographics, specific surgical procedures, publication status, or study period. The bibliographies of the retrieved studies were manually searched to identify other potentially relevant articles. The flow of study selection is shown in Fig. 1.

2.2. Inclusion and exclusion criteria

All included studies contained original data published in the English language on patients undergoing revision cubital tunnel surgery. Included studies were required to report the types of both primary and revision surgeries as well as intraoperative findings, outcomes, and complications of revision surgery. Single-case reports, along with studies involving cadavers and in vitro or animal models, were excluded.

2.3. Quality appraisal

Eight reviewers (M.A., O.A., S.A., W.A., J.M.K., Y.C.S., H.J.L. and E.K.) independently reviewed each article, with the decision to include or exclude any study based on discussion and consensus. The level of evidence of each study was determined using the Oxford Centre for Evidence-Based Medicine criteria [8]. The decision to include or exclude studies was also discussed with two expert orthopedic surgeons specializing in the elbow surgery (K.H.K. and I.H.J.).

2.4. Data extraction and analysis

Data were extracted from the text, figures, tables, and supplementary material of each of the included studies. These data included demographic characteristics, follow-up duration, types of primary and revision surgeries, intraoperative findings during revision surgery, outcomes of revision surgery, and complications of revision surgery. These data were summarized in tables in Microsoft Office Excel (2013, Microsoft, Redmond, WA, USA).

3. Results

3.1. Demographic data

An overview of the article selection process is shown in Fig. 1. Of the 191 articles identified in our search, 10 were included in the present review. According to the Oxford Centre for Evidence-Based Medicine [8], nine studies were categorized as level 4 (case series) and one as level 3 (case-control study). All included studies were single center studies.

The 10 studies included 195 elbows of 192 patients who underwent revision cubital tunnel surgery, including 102 men (53.1%) and 90 women (46.9%), ranging in age from 15 to 75 years, with the largest proportion aged in their 40s (Table 1). Sixty-two patients (32.3%) presented with recurrent and 130 (67.7%) with persistent cubital tunnel syndrome. The remission period in those with recurrent cubital tunnel syndrome ranged from 6 to 21 months. However, two studies did not specify the remission period, and one study reported a remission period for only 23 of 40 patients, categorizing them according to patient-reported outcome measures (PROMs) [3]. Mean ± SD remission periods were 24.8 ± 26.0 months in 11 patients with subjectively better results, 9.2 ± 3.7 months in eight with no change in remission period, and 10.9 ± 10.8 months in four with subjectively worse results. The follow-up period ranged from 6 to 113 months. Two studies described the history and/or comorbidities associated with cubital tunnel syndrome [1–9].

3.2. Types of primary surgery

Three studies included patients who underwent primary surgery alone [11,13,15], whereas the remaining studies included those who underwent multiple revision surgeries (mean, 1.04–2.7). One study did not specify the type of primary surgery in each patient, although the techniques in that study included simple decompression, decompression combined with medial epicondylectomy, or anterior submuscular or intramuscular transposition with internal neurolysis. Of 195 elbows, 20 (10.2%) underwent a second revision surgery and three (1.5%) underwent a third revision surgery; one patient underwent five revision surgeries [9]. The specific type of primary surgery was not reported for 17 elbows. Of 178 elbows, 88 (49%) underwent non-transposition surgery (in situ decompression, medial epicondylectomy, or external neurolysis) and 90 (51%) underwent transposition surgery (subcutaneous or submuscular/intramuscular transposition) for primary surgery. The most common type of primary surgery was subcutaneous transposition (33%), followed by in situ decompression (27%), submuscular/intramuscular transposition (13%), medial epicondylectomy (9%), and external neurolysis (9%). In the present review, we intentionally combined elbows that underwent submuscular and intramuscular transposition to simplify data pooling and analysis.

3.3. Types of revision surgery

With the exception of one study, which included patients who underwent two types of revision surgery (submuscular and subcutaneous transposition) [12], only one technique was used in each of the included studies. The most common technique was submuscular transposition (75%), followed by nerve wrap (15%), subcutaneous transposition (5%), external neurolysis (5%), and in situ decompression (3%). Different types of submuscular transposition techniques are used for revision surgery; however, two studies did not specify the submuscular transposition technique that was used [1–9,15]. The Learmonth technique was used in three studies that included a total of 44 elbows [9,15]. In this technique, the flexor pronator muscles are divided close to their origins, followed by medial transposition of the ulnar nerve and muscle suturing [17]. One study (six elbows) described a modification of the previous submuscular transposition technique [14], in which the medial epicondyle was divided with the muscles attached, the ulnar nerve was transposed, and the epicondyle was repositioned and fixed with wire sutures [18]. In addition, musculofascial lengthening (Z-lengthening) was used in two studies that included 59 elbows.

3.4. Intraoperative findings and pathology level

All studies described the intraoperative findings of revision surgery. The most frequent pathology was perineural scarring/fibrosis (79%), followed by ulnar nerve instability/subluxation (7%), pseudoneuroma (5.6%), neuroma (4.2%), nerve flattening (2.8%), and nerve kinking (1.4%). Six studies reported the level of pathology [1–3,11,13–15,17,18], the most common of which was the medial intermuscular septum (33%), followed by both cubital tunnels and the arcade of Struthers (10%), the arcade of Osborne (8%), the medial epicondyle (7%), the previous transposition site (7%), the common flexor aponeurosis (6%), the deep flexor pronator aponeurosis (4%), the entrance to the flexor carpi ulnaris (4%), and the antebrachial fascia (1%). The level of pathology was not specifically described in 17 elbows (11%) [3–9,11,15]. One study

Table 1
Demographic characteristics of the patients in each study.

No.	Article (year)	Design	Level of evidence	No. of patients (elbows)	Average age, years (range)	Male/female	Number of patients in remission	Average time to revision surgery, months (range)	Follow-up period	Associated history/comorbidities
1	Gabel et al. (1990) [9]	Retrospective case series	4	30 (30)	42.3 (18–75)	17/13	10	NA	43.7 (24–113) mo	Alcoholism (3) Hypertension (4) Obesity (6) DM (1) RSD (2)
2	Rogers et al. (1991) [10]	Retrospective case series	4	14 (14)	36 (16–59)	8/6	None	9 (2–24)	19 (9–48) mo	NA
3	Dagregorio et al. (2004) [11]	Retrospective case series	4	9 (9)	47 (32–66)	7/2	6	NA	24 mo	NA
4	Vogel et al. (2004) [12]	Retrospective case series	4	18 (18)	44 (25–67)	9/9	11	54 (4–480)	34 (6–84) mo	NA
5	Aleem et al. (2014) [1]	Case control	3b	28 (28)	55 (32–72)	11/17	21	NA	3.4 (2.0–6.2) y	Workers' compensation (4)
6	Papatheodorou et al. (2015) [13]	Retrospective case series	4	12 (12)	45 (30–58)	8/4	Not specified	18 (5–60)	41 (24–61) mo	None
7	Holmberg (1991) [14]	Retrospective case series	4	14 (16)	52.1 (15–74)	12/2	Not specified	20.6 (3–93)	18.2 (3–30) mo	NA
8	Bartels et al. (2004) [3]	Retrospective case series	4	40 (41)	M 49.5 (29.3–70.2) F 50.1 (24.6–75.4)[a]	15/25	23	Not specified[b]	2.4 ± 1.5 y[c]	NA
9	Broudy et al. (1978) [15]	Retrospective case series	4	10 (10)	42 (18–71)	7/3	6	13	14.5 mo	NA
10	Kokkalis et al. (2010) [16]	Retrospective case series	4	17 (17)	51 (30–67)	8/9	None	NA	44 (24–87) mo	NA

NA: not available; M: male; F: female; DM: diabetes mellitus; RSD: reflex sympathetic dystrophy.

[a] Bartels et al. reported age in men and women

[b] Bartels et al. reported the average time to revision surgery in only 23 patients and categorized them into three groups based on patient-reported outcome measures (PROMs)

[c] Bartels et al. reported the average time to revision surgery as mean ± standard deviation.

Table 2
Types of primary surgery, intraoperative findings, level of pathology, number of prior surgeries, and types of revision surgery in each study.

No.	Article (year)	Type of primary surgery[a]	Intraoperative findings	Level of pathology	Presence of MABC neuroma	Average level of pathology	Average prior surgery	Type of revision surgery
1	Gabel et al. (1990) [9]	Neurolysis (13%) In situ decompression (9%) Medial epicondylectomy (4%) Subcutaneous transposition (54%) Intramuscular transposition (13%) Submuscular transposition (7%)	Perineural scarring	AS (24%) MIS (33%) CT (14%) Osborne arcade (19%) DFPA (10%)	NA	2.3	1.53	Submuscular transposition (80%) Not specified (20%)
2	Rogers et al. (1991) [10]	Medial epicondylectomy (44%) In situ decompression (6%) Subcutaneous transposition (37%) Intramuscular transposition (13%)	Perineural fibrosis (92.8%) Ulnar nerve subluxation (7.2%)	MIS (48%) ME (28%) CT (4%) Not specified (20%)	7	1.7	1.14	Submuscular transposition with external neurolysis
3	Dagregorio et al. (2004) [11]	Submuscular transposition	Perineural scarring	Previous transposition site	NA	NA	1.0	External neurolysis
4	Vogel et al. (2004) [12]	Medial epicondylectomy (11%) Subcutaneous transposition (89%)	Perineural scarring (55%) Nerve instability (28%) Neuroma (17%)	AS (21 %) MIS (42 %) Common flexor aponeurosis (37 %)	Yes[b]	1.3	1.11	Submuscular transposition with Z-lengthening
5	Aleem et al. (2014) [1]	In situ decompression (93%) Subcutaneous transposition (7%)	Perineural scarring Nerve instability Incomplete release[b]	NA	NA	NA	1.07	Submuscular transposition
6	Papatheodorou et al. (2015) [13]	In situ decompression with medial epicondylectomy (33%) Subcutaneous transposition (17%) Submuscular transposition (50%)	Perineural scarring	NA	NA	NA	1.0	Porcine extracellular matrix nerve wrap (with/without minimal medial epicondylectomy)
7	Holmberg (1991) [14]	In situ decompression	Perineural scarring	NA	1	NA	1.3	Submuscular transposition (75%) Subcutaneous transposition (25%)
8	Bartels et al. (2004) [3]	In situ decompression (51%) Medial epicondylectomy (10%) Subcutaneous transposition (39%)	Perineural scarring (63%) Pseudoneuroma (19%) Nerve flattening (9%) Nerve subluxation (2%) Intact MIS (2%) Nerve kinking (5%)	Entrance of FCU (22%) CT (15%) ME (19%) Not specified (44%)	NA	0.65	1.04	Submuscular transposition
9	Broudy et al. (1978) [15]	Submuscular transposition (50%) Subcutaneous transposition (50%)	Perineural scarring (60%) Fascial sling compression (30%) Neuroma in continuity (10%)	MIS (65%) CT (14%) Antebrachial fascia (7%) Fascia sling from previous transposition (14%)	NA	1.4	1.0	Submuscular transposition
10	Kokkalis et al. (2010) [16]	Not specified	Perineural scarring	NA	Yes[b]	NA	2.7	Saphenous nerve wrap

NA: not available; MABC: medial antebrachial cutaneous nerve; AS: arcade of Struthers; MIS: medial intermuscular septum; ME: medial epicondyle; CT: cubital tunnel; DFPA: deep flexor pronator aponeurosis; FCU: flexor carpi ulnaris.

[a] Patients may have undergone > 1 revision surgery.

[b] The study reported pathology but did not specify the number of patients with each pathology.

reported that the highest level of pathology was 2.3 times for each elbow[8]. Four studies reported that medial antebrachial cutaneous nerve neuroma was an associated intraoperative finding in 32% of elbows [10,12,14,16–18]. Table 2 summarizes the types of primary surgery, intraoperative findings, levels of pathology, number of prior operations, and types of revision surgery in these patients.

3.5. Outcomes

All of the included studies made a qualitative assessment of the outcomes, whereas only six made a quantitative assessment (Table 3) [3–9,11,13–15]. Qualitative methods included assessments of pain, sensory outcomes, motor outcomes, and satisfaction and PROMs, whereas quantitative methods included grip and pinch strength, two-point discrimination, and nerve conduction velocity. Pain was the only outcome measure evaluated in all of the included studies. The outcome measures in each study are shown in Table 4. Owing to the variability in outcomes among the included studies, we categorized the outcomes into three groups: (1) complete improvement, (2) partial improvement, and (3) no improvement. In three of the studies, more patients showed no improvement than complete or partial improvement [1–9,11,13–15]. Residual symptoms were reported in all studies, whereas only two studies reported complications, including flexion contracture of the elbow and transient leg swelling at the donor site [9–11,13,14,16–18].

4. Discussion

The surgical procedures for cubital tunnel syndrome essentially fall into two general categories. The first category involves in situ (or simple) decompression and medial epicondylectomy, whereas the second category involves transposition procedures, which involve moving the nerve a considerable distance around the medial epicondyle. Transposition surgery can be classified as subcutaneous, intramuscular, or submuscular.

Attempts have been made to compare types of index and revision surgery. The present study reported that transposition surgery as an index procedure was associated with a slightly higher incidence of revision transposition surgery. Transposition surgery, which moves the nerve away from its native bed, is associated with a higher rate of complications as additional steps are required to complete the procedure [19]. An interesting decision-analysis model study reported that simple decompression was considered the treatment of choice for cubital tunnel syndrome, with submuscular transposition a salvage procedure [20]. There is a tendency of performing transposition surgery for case with severe clinical presentation, for example, ulnar nerve subluxation or altered anatomy as a result of earlier fracture or arthrosis of elbow joint [19]. Consequently, the result will be relatively unsatisfactory following the disease background. The present study found that 49% patients underwent decompression surgery and 51% patients underwent transposition surgery as an index procedure that require the revision surgery. This number is quite comparable. Therefore we postulate that type of index surgery does not correlate directly to the recurrence or persistent symptoms of cubital tunnel syndrome. We think that this is due to the failure to address all compression sites existed in each cases.

The present study showed that the most common entrapment site detected during revision surgery was the proximal medial intermuscular septum, and similar findings have been observed during primary surgery for cubital tunnel syndrome [21]. Seven structures distal to the medial epicondyle may prevent transposition of the ulnar nerve to a straight-line course [21]. Dissection up to 12 cm distal to the medial epicondyle is necessary to address all tethering structures. Inadequate excision of either the proximal or distal intermuscular septum can create a severe kink in the anteriorly transposed ulnar nerve, and knowledge of ulnar nerve topography is important to prevent further kinking. Normal structures that are not sources of compression when the nerve is in its native position could become new sources of compression when the nerve is transposed. The success rate of transposition surgery is not determined by the properties of the designated tissue to which the nerve is transposed, but rather by the ability to create an untethered course for the nerve, preventing it from kinking along its entire length. In this study, 67% of 195 elbows showed persistent cubital tunnel syndrome reflecting the failure to address sites of compression in the prior surgery.

The most common intraoperative finding was perineural scarring/fibrosis, with the latter being the chief cause of refractory cubital tunnel syndrome. Scar and adhesion formation around the nerve is a gradual, cumulative process in which symptoms are relieved for a period of time prior to the onset of recurrent neuritic symptoms. The mini-invasive approach has becoming a trend in the aim to preserve blood supply therefore preventing the perineural fibrosis. A case series of 30 patients with mini-invasive ulnar nerve transposition resulted in excellent outcome for primary cubital tunnel syndrome surgery [22].

The optimal surgical technique for treating refractory cubital tunnel syndrome remains unclear. Few well-designed randomized trials have compared these surgical procedures, and none have directly compared > 2 possible surgical interventions. Moreover, although all studies to date have reported favorable functional outcomes, almost every outcome in the studies included in this review varied widely, including the remission period, intraoperative findings, level of pathology and average rates, average number of prior surgeries, and surgical techniques. Six of the 10 included studies reported remission periods, implying recurrent cubital tunnel syndrome. Conversely, two studies reported that none of the patients had a remission period, indicating persistent cubital tunnel syndrome. Moreover, both of these studies reported the occurrence of medial antecubital cutaneous (MABC) neuroma. Medial cutaneous nerve injuries at the time of index surgery are known to compromise the results of revision surgery, with up to 40% of patients having neuromas of cutaneous nerves. Recommended treatments include neuroma resection, stump cauterization, and implantation of the injured MABC into a muscle [23]. It is also important to define treatment failure. The need for revision surgery as an objective endpoint for treatment failure can vary. Our findings suggest that revision surgery is warranted if symptoms are considered significant by both the patient and the surgeon.

All of the reviewed studies reported an average outcome for revision surgery of cubital tunnel syndrome. All of the included studies reported residual symptoms after revision surgery, with paresthesia being the most common. This study revealed that transposition surgery was the most common type of revision surgery. Transposition surgery may result in a loss of the sinusoidal extrinsic blood supply to the ulnar nerve, causing paresthesia as a residual clinical symptom. Of 195 elbows, 10 (5.1%) had permanent flexion contractures. Transient leg swelling at the donor site was also reported as a temporary complication of nerve wrapping surgery. The most frequent method for assessing complications was qualitative pain measurement, with all included studies reporting pain relief with revision surgery. Unfortunately, the methods used to measure pain were not consistent and prevented a direct comparison of their results.

The present study showed that 32.3% patients requiring revision surgery had a remission period ranging from 6–21 months.

Table 3
Qualitative and quantitative outcome measures in each study.

No.	Article (year)	Qualitative measurement				Quantitative measurement			
		Pain	Sensory	Motor	Satisfaction	Grip strength	Pinch strength	2 PD	NCV
1	Gabel et al. (1990) [9]	Improved 1.3 points	Improved 1.0 points	Improved 0.6 points	NA	NA	NA	NA	NA
2	Rogers et al. (1991) [10]	Pain and paresthesia alleviated in all patients		Improved (8) No improvement (3)	NA	Residual pinch and grip strength deficit of 10%–20% compared with the normal side		NA	NA
3	Dagregorio et al. (2004) [11]	No pain (4) Relief (4) Worse (1)	Good (4) Fair (4) Poor (1)		NA	27% improvement (4) 21% improvement (4) 10.5% improvement (1)	47% improvement (4) 61.5% weaker than contralateral (1) No data (4)	Normal (4) 5–6 mm (4) 10 mm (1)	Normal (4) Subnormal sensory action potential amplitude (4) No sensory potential and decreased motor NCV (1)
4	Vogel et al. (2004) [12]	No pain (4) Occasional (10) Frequent (3) Constant (1)	NA	NA	Satisfied (14) Not satisfied (4)	32% improvement	NA	Improved (4) Normal (10) Absent (1) No report (3)	NA
5	Aleem et al. (2014) [1]	PROMs: 79% symptomatic relief McGowan scale: 25% improvement on grading Levine-Katz questionnaire: moderate remaining symptoms				28 kg (range, 8–63 kg)	5 kg (range, 3–16 kg)	7 mm (range, 6–15 mm)	NA
6	Papatheodorou et al. (2015) [13]	Average VAS score decreased from 8.5 to 1.7	NA	NA	Average score improved from 1.7 to 8.6	Improved from 41% to 86%	Improved from 64% to 83%	Improved from 10.4 mm to 7.6 mm	NA
7	Holmberg (1991) [14]	First revision: No pain (3) Improved (4) Unchanged (9) Second revision (6): No pain (4) Improved (1) Unchanged (6)	First revision: No paresthesia (1) Improved (6) Unchanged (9) Second revision (6): No paresthesia (3) Improved (2) Unchanged (1)	First revision: No weakness (2) Improved (4) Unchanged (8) Second revision (6): No weakness (1) Improved (6) Unchanged (8) Worse (1)	NA	NA	NA	NA	NA

Table 3 (*Continued*)

No.	Article (year)	Qualitative measurement				Quantitative measurement			
		Pain	Sensory	Motor	Satisfaction	Grip strength	Pinch strength	2 PD	NCV
8	Bartels et al. (2004) [3]	Average VAS score: 4.7 ± 3.6 PROMs: 42% improved, 39.5% unchanged, 18.5% worse	Diminished pinprick perception (6)	Normal (7) Improved (12) No change (19) Worse (10)		NA	NA	NA	NA
9	Broudy et al. (1978) [15]	Improved (8)	Paresthesia improved (7) Sensory loss improved (5)	Weakness improved (6)	NA	NA	NA	NA	NA
10	Kokkalis et al. (2010) [16]	Average VAS score decreased from 7.4 (range, 6–9) to 2.9 (range, 2–5)	NA	NA	NA	Average ratio increased from 0.41 ± 0.3 to 0.59 ± 0.4	Mean ratio increased from 0.49 ± 0.3 to 0.57 ± 0.3	Improved from 12.1 ± 3.1 to 10.6 ± 2.4 (17) Improved 2 mm (9)	Motor NCV: improved from 43 m/s (range, 38–49 m/s) to 45 m/s (range, 39–49 m/s) Sensory NCV: improved from 38 m/s (range, 33–44 m/s) to 42 m/s (range, 37–47 m/s)

NA: not available; 2 PD: two-point discrimination; NCV: nerve conduction velocity; VAS: visual analog scale; PROMs: patient-reported outcome measures.

Table 4
Summary of functional outcomes.

No.	Article (year)	Outcome measurement tool	Summary of results (%)			Residual symptoms				Complications
			Complete improvement	Partial improvement	No improvement	Pain	Paresthesia	Muscle weakness	Others	
1	Gabel et al. (1990) [9]	Gabel and Amadio rating system	7	17	6	+	+	+		Flexion contracture (30%)
2	Rogers et al. (1991) [10]	Qualitative (pain, sensory, motor)	11	None	3			+		NA
3	Dagregorio et al. (2004) [11]	Wilson and Kraut classification system	4	4	1		+			NA
4	Vogel et al. (2004) [12]	Qualitative (pain, satisfaction) Quantitative (grip strength, 2 PD)	3	7	8		+	+		NA
5	Aleem et al. (2014) [1]	Levine-Katz questionnaire PROMs McGowan grading system	1	6	21		+			NA
6	Papatheodorou et al. (2015) [13]	Qualitative (pain, satisfaction) Quantitative (grip and pinch strength, 2 PD)	None	12	None	+	+			NA
7	Holmberg (1991) [14]	Qualitative (pain, sensory, motor)	1	6	9	+	+	+	Claw hand	NA
8	Bartels et al. (2004) [3]	Qualitative (pain, sensory, motor) PROMs	Clinical assessment: 8 PROMs: 1	24 16	3 24	+	+		Cold intolerance	NA
9	Broudy et al. (1978) [15]	Qualitative (pain, sensory, motor)	1	9	None		+	+		NA
10	Kokkalis et al. (2010) [16]	Qualitative (pain) Quantitative (grip and pinch strength, 2 PD, NCV)	None	17	None	+				Transient leg swelling

NA: not available; VAS: visual analog scale; 2 PD: two-point discrimination; PROMs: patient-reported outcome measures; NCV: nerve conduction velocity.

Therefore, we recommend to have a follow up as long as 24 months in primary cubital tunnel syndrome surgery in the attention for recurrence.

Revision cubital tunnel surgery yields average functional outcomes. However, the variability in outcomes reported in prior studies prevents determination of the optimal surgical procedure. A consensus on reporting functional outcomes after cubital tunnel surgery is urgently needed.

This study had several limitations. First, data from the included studies were collected retrospectively. Second, 2 studies had wide interval of age of reviewed studies population indicate the different population group [13–16]. This may indirectly affect the functional outcome considering superiority outcome usually expected from younger population group. Third, study outcomes varied widely, preventing a direct comparison of outcomes and highlighting the need for standardized methods of reporting functional outcomes following peripheral nerve entrapment surgery, especially for cubital tunnel syndrome. Third, the heterogeneity of the reviewed studies refrain as to determine the optimal surgical technique for treating refractory cubital surgery.

5. Conclusion

Revision cubital tunnel surgery provides average functional outcomes with transposition surgery as the most common index surgery performed. The most common pathology is perineural scarring at the level of medial intermusculare septum. Transposition surgery was the most common type of revision surgery. We advocate a minimum of 24 months follow up for the attention of recurrence case. The variability in outcomes assessed in prior studies prevents a determination of the optimal surgical procedure. There is an urgent need for consensus on reporting functional outcomes after cubital tunnel surgery.

Disclosure of interest

The authors declare that they have no competing interest.

Funding sources

This research was supported by the convergence technology development program for bionic arm through the National Research Foundation of Korea (NRF) funded by the Ministry of Science & ICT (No. 2014M3C1B2048422).

Authors' contribution

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Acknowledgments

We thank the National Research Foundation of Korea (NRF) for supporting our study through convergence technology development program for bionic arm.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.otsr.2019.03.020.

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