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Research article

Anterior transposition and positioning via helix sling method in cubital tunnel syndrome: An open-label, retrospective trial of maximum 5-year follow-up

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ABSTRACT

Background: Ulnar nerve transposition is used for cubital tunnel syndrome (CuTS) with nerve instability. The aim is to report a modified technique for ulnar nerve transposition using medial intermuscular septum and Osborne's ligament as a double-strand helix sling to recreate a sliding channel for the ulnar nerve and the functional outcomes at follow-ups.

Methods: Twenty-five patients with persistent CuTS underwent nerve release and subcutaneous transposition from January 2017 to January 2022 in our institute. Among them, 9 patients were excluded due to incomplete medical records, lack of follow-up history, or bilateral limb numbness. The medial intermuscular septum with one end attached was excised to rebuild a tension-free double-strand helix sling by anchoring at the residue of Osborne's ligament. The modified Mc-Gowan classification was applied to evaluate the disease severity preoperatively. The quick disability of arm and shoulder and hand (quickDASH) questionnaire and visual analogue scale (VAS) scores were used to evaluate pre- and postoperative symptoms. Ultrasound imaging was utilized for nerve structure evaluation before surgery and at follow-ups.

Results: Sixteen out of twenty-five patients received follow-ups postoperatively (ranging from 9 to 69 months, 36 months in average). No findings indicated subluxation of ulnar nerve or recompression by ultrasound imaging examination. According to quickDASH and VAS scores and physical examination, 14 out of 16 patients showed postoperative improvement in symptoms and function at final follow-ups.

Interpretation: In this modified technique, the medial intermuscular septum and Osborne's ligament can create tension-free helix sling for stable and smooth sliding and preventing subluxation after nerve transposition, which is highly effective and safe for CuTS treatment.

1. Introduction

Cubital tunnel syndrome (CuTS) is a common nerve compression syndrome observed in the upper extremity among sports, exercise

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injuries and trauma. It has an incidence of about 20 cases per 100,000 person-years [1]. Compression of the ulnar nerve along its course at the elbow can result in permanent loss of sensation, muscle weakness, and joint contractures [2]. Conservative treatment measures, including patient education and behavior modification, oral NSAIDs medications, physical therapy, and corticosteroid injections, are effective for about 50 % of the time [3]. To avoid constant dysfunction, timely surgical treatment is necessary if conservative management is not successful. The surgical intervention rates are increasing in recent years in western countries [4]. Decompression of the nerve alone, decompression with ulnar nerve anterior transposition, and medial epicondylectomy are the main surgical procedures to free the ulnar nerve from Arcade of Struthers, medial muscular septum, medial collateral ligament, Osborne's ligament and deep flexor-pronator mass [5]. Though the present surgical management acquires a relatively good result, the optimal surgical management for CuTS remains undetermined [6].

Among different anterior transposition techniques, sling methods using fascia or muscle tissues were considered to provide a restraint to posterior subluxation of the ulnar nerve following anterior transposition. Pribyl et al. and Tan et al. reported the use of the medial intermuscular septum as a fascial sling during anterior transposition of the ulnar nerve respectively [7,8]. Pribyl and colleagues proposed the very early generation of single-limb sling technique [7]. Meanwhile, Tan et al. modified it by creating V-shape double limbs [8]. However, both techniques did not basically prevent the nerve from tenting or kinking over inside the channel. In addition, simple suture of the intermuscular septum with the medial epicondyle may not evidently decrease the likeliness of re-subluxation of the ulnar nerve [3].

Therefore, the major goal of this research is to report a helix sling technique with the medial intermuscular septum anchoring at the residue of Osborne's ligament and to evaluate its functional outcomes. We hypothesize that it realizes anterior subcutaneous transposition of the ulnar nerve and reduces the likeliness of subluxation. It is primarily because that the tissues from two compression sites can be reused to enhance the stable anchor positioning of the sling structure. The focus is the functional outcomes of these patients treated by this technique at different time points of follow-up.

2. Materials and methods

2.1. Study design

This study was performed based on patients who were diagnosed with CuTS and were operated between January 2017 and January 2022 by a single senior surgeon in an open-label, non-randomized, retrospective, single-center style. The institutional review board of our hospital reviewed the research protocol and approved this study (no. 2020145). Informed consent was obtained from each patient. The inclusion criteria for patients were: 1) patients aged from 18 to 70 years old, 2) severe CuTS based on the modified Mc-Gowan

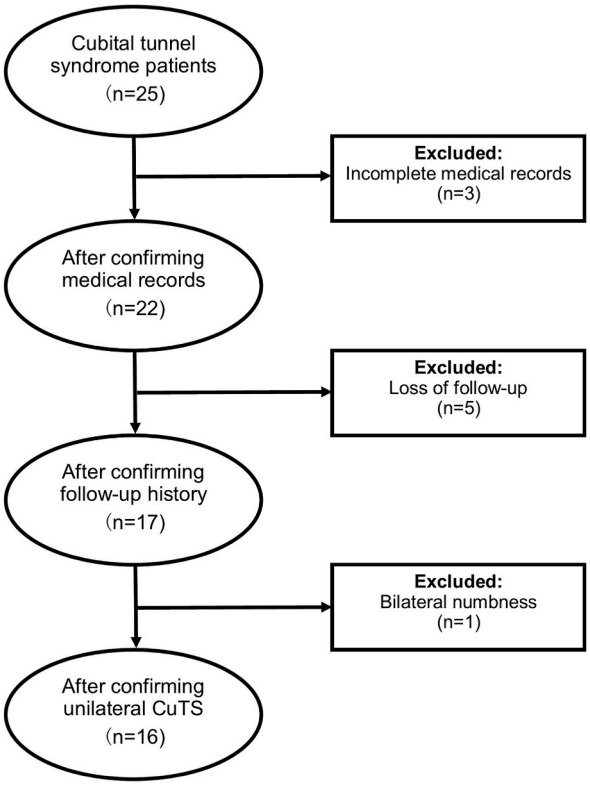

Fig. 1. Flow chart of patient enrollment.

classification, 3) CuTS symptoms lasting >0.5 years or no improvement in symptoms after previous conservative treatment (including injection or other physical therapies) for over 12 weeks, 4) normal contralateral upper extremity for compared study, and 5) intermittent or persistent nerve instability. The following patients should be excluded: 1) revision surgical treatment of CuTS, 2) infectious, endocrinal or carcinoma diseases, and 3) refusal of participation.

There were 25 patients diagnosed with severe CuTS between January 2017 and January 2022 in this Orthopedic center. Among them, 9 patients were excluded due to incomplete medical records, lack of follow-up history, or bilateral limb numbness (Fig. 1). Physical examination and ultrasound imaging were used to confirm the diagnosis of CuTS for all these patients. Each patient was preoperatively examined and the following data were recorded: sex, age, affected side, clinical manifestations and duration of symptoms. The modified Mc-Gowan classification was applied to measure the clinical manifestations preoperatively. The quick disability of arm and shoulder and hand (quickDASH) and visual analogue scale (VAS; 0 = no numbness, 10 = most severe pain)) scores were used to evaluate the pre and postoperative symptoms and functions.

2.2. Surgical technique

All procedures were performed under standard preparation (draping the arm, and inflation of tourniquet). The shoulder was in an abduction and external rotation position and the elbow was placed at a 90° flexion position. A medial skin incision was made above the cubital tunnel for about 8 cm long. The fascia and other subcutaneous tissues were carefully dissected to the triceps muscle and flexor-pronator muscles. The articular branch of the ulnar nerve that traversed the surgery area were also carefully isolated and protected. Then, the ulnar nerve came in to view clearly from the cubital tunnel to the medial intermuscular septum, and was released in the whole course. The inferior ulnar collateral vessels were protected and kept in most cases (Fig. 2A). Then, the division of the medial intermuscular septum was made around 7–8 cm away from the medial epicondyle. A long and thickened sheet of the medial intermuscular septum was cut carefully with the only attachment to the medial epicondyle and its distal end wrapped the nerve from behind (Fig. 2B) after the anterior transposition of the ulnar nerve. Next, we adopted a helix sling technique by inverting the one end of the septum into a helix structure and anchored its midpoint to the residue of Osborne's ligament that was partially removed during nerve release. Finally, the end of the long sheet was sutured and positioned at the flexor carpi ulnaris (Fig. 2C&D). It can realize anterior subcutaneous transposition of the ulnar nerve. Simultaneously, the tissues from two compression sites were reused to enhance the stable anchor positioning of the sling structure without potential nerve subluxation. The entire helix loop of the septum should allow certain movement of the ulnar nerve without interfering elbow activity. No compression or subluxation of the ulnar nerve was noticed during elbow flexion and extension after nerve transposition under anesthesia in the surgery (Supporting Fig. 1). After it was

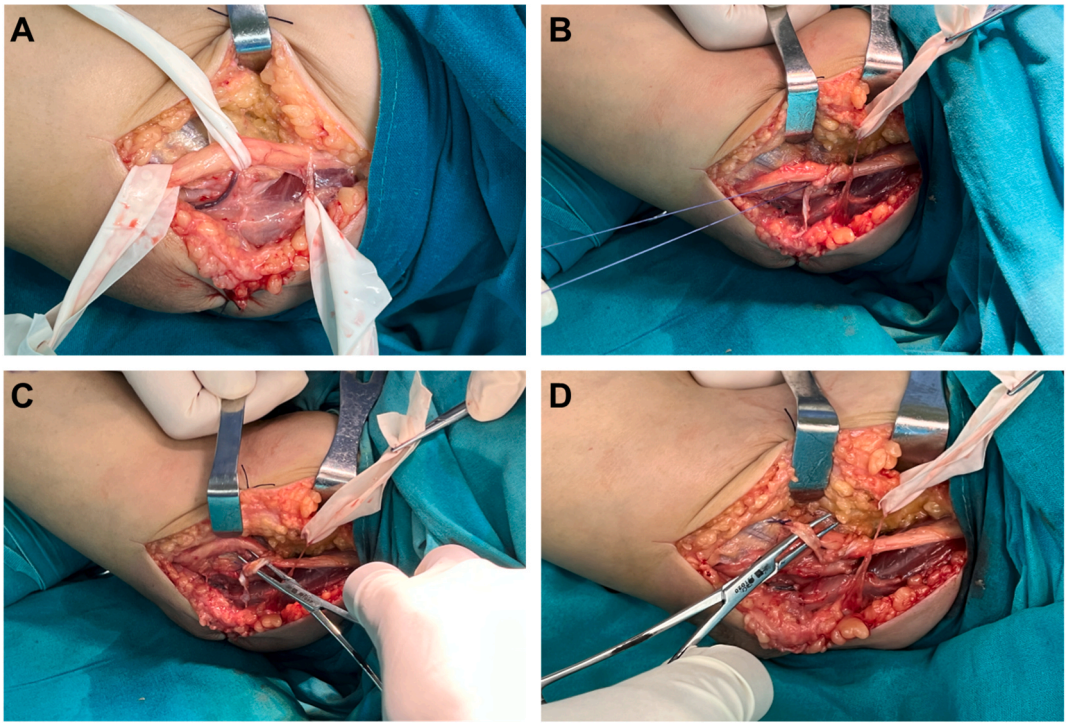

Fig. 2. The surgical release and anterior transposition of the ulnar nerve with helix sling technique. (A) Exposure of the ulnar nerve and protection of nerve branch and concomitant vessels. (B) Dissection of one thin sheet of the medial intermuscular septum. (C) Anchoring of the midpoint of medial intermuscular septum at the residue of the Osborne's ligament. The forceps show no compression of medial intermuscular septum on the nerve. (D) No compression of medial intermuscular septum on the nerve at the bend site.

confirmed, the wound of the arm was closed and cast mobilization was performed. After 2 weeks of surgery, the removal of the cast was carried out along with dressings and sutures before full activity of the elbow started.

2.3. Follow-up and postoperative evaluation

We set follow-ups at 6, 9 and $\geq$ 12 months after surgery. Ultrasound imaging, as the primary assessment tool, was performed to measure the thickness diameter, transverse diameter and maximum cross-section area of the ulnar nerve within the cubital tunnel at final follow-up. Numbness or stinging at rest was quantified using VAS. We measured key pinch activity, clip paper test and Froment sign. The function of the hand, wrist, arm, and elbow were evaluated by the quickDASH questionnaire. Statistical analysis: Continuous variables and categoric variables were evaluated and displayed by numbers.

3. Results

The demographic data, such as sex, age, duration of symptoms, dominant side, affected side, and related trauma history were displayed in Table 1. The mean follow-up time was 36 months (ranging from 9 to 69 months).

Clinical manifestation and symptoms, including limb numbness, muscle atrophy, clinch activity, clip paper test and Froment sign were shown in Table 2. All patients displayed different levels of arm, hand or finger numbness and muscle atrophy preoperatively. Some of them even developed claw hands and contracture of the first web space (Fig. 3A–C). After anterior transposition of the ulnar nerve by helix sling technique, only 2 out of 16 patients experienced limited little finger numbness at final follow-ups. Other patients recovered normal hand appearance and functions (Fig. 4A–F). There were no patients who showed positive clip paper test and only 1 out of 16 patients displayed positive Froment sign at the final follow-up.

The clinical outcomes, such as pain and limb function were measured by VAS and quickDASH scores respectively. The data were displayed in Table 3. The average VAS score improved from 6.5 to 2. The average quickDASH score improved from 45 to 21.

The ultrasound imaging exam was also included to evaluate some physical parameters of the ulnar nerve within the cubital tunnel. The images showing the ulnar nerve above and below the elbow were taken preoperatively and at follow-ups (Fig. 5A–F). The ulnar nerves were in semi-subluxation or unstable condition before surgery and were stable at follow-ups in this study. The data of the nerve structure parameters were displayed in Table 3. The thickness diameter of the nerve at the cubital tunnel level decreased by 1.5 mm in average. The transverse diameter decreased by 4.5 mm. In addition, the maximum cross-section area decreased by 9.5 mm^2.

4. Discussion

This study is focused on a modified technique for ulnar nerve transposition using medial intermuscular septum and Osborne's ligament as a double-strand helix sling to recreate a sliding channel for the ulnar nerve. Sixteen out of twenty-five patients received follow-ups postoperatively (ranging from 9 to 69 months, 36 months in average). No findings indicated subluxation of ulnar nerve or recompression by ultrasound imaging examination. According to quickDASH and VAS scores and physical examination, 14 out of 16 patients showed postoperative improvement in symptoms and function at final follow-ups.

The surgical treatment of CuTS has been practiced and discussed a lot in the past decades [9,10]. Many strategies of nerve release include anterior transposition and simple release, or wrapping the nerve with native tissues [11]. It is appropriate to use anterior transposition technique in the ulnar nerve release to prevent postoperative nerve contraction or entrapment in CuTS with nerve instability [12]. There is no prominent improvement in decreasing nerve strain after simple release and decompression [13]. Among the different anterior transposition techniques, sling technique using the medial intermuscular septum was practiced before. It has the advantage of removing and reusing the compression tissue (medial intermuscular septum) as a protective band to reduce the occurrence of nerve subluxation to some degree [8]. However, it may increase the likeliness of elbow stiffness and affect the range of motion due to relatively low mechanical strength for stabilizing the ulnar nerve and consequent mobilization of the elbow joint [14]. According to the anatomical studies, there are a few common sites to compress the ulnar nerve, including Arcade of Struthers, medial muscular septum, medial collateral ligament, Osborne's ligament and deep flexor-pronator mass [5]. In this study, we released the

Table 1
Demographic data.

Parameter	
M/F (n)	9/7
Age (y)	49 (21–70)
Duration (m)	25 (3–120)
Dominant side (L/R)	2/14
Affected side (L/R)	5/11
Trauma (Y/N)	9/7

(n) = number.
(y) = years.
(m) = months.
(L/R) = left/right.
Y/N = yes/no.

Table 2
Clinical manifestation and symptoms (preoperative and final follow-up).

No.	Clinical manifestation and symptoms (preoperative)	Clinical manifestation and symptoms (final follow-up)	Clip paper test (preoperative/final follow-up)	Froment sign (preoperative/final follow-up)
1	right hand numbness and thenar muscle atrophy	no numbness	positive/negative	positive/negative
2	numbness of the left little finger and ulnar side of ring finger and thenar muscle atrophy	no numbness	negative/negative	negative/negative
3	numbness of the left little finger and ulnar side of ring finger and thenar muscle atrophy	no numbness	negative/negative	negative/negative
4	right hand numbness, and forearm and hand muscle atrophy	no numbness	positive/negative	positive/negative
5	numbness of the right little finger and ulnar side of ring finger, thenar muscle atrophy and claw hand	no numbness, no claw hand	positive/negative	positive/negative
6	numbness of the left little finger and ulnar side of ring finger, thenar muscle atrophy and claw hand	no numbness, no claw hand	positive/negative	positive/negative
7	numbness of the right little finger and ulnar side of ring finger	no numbness	positive/negative	positive/negative
8	numbness of the right little finger, ring finger and ulnar side of middle finger, pinch dysfunction, and claw hand	littile finger numbness, functional pinch activity, no claw hand	positive/negative	positive/negative
9	thenar muscle atrophy, pinch dysfunction and claw hand	no numbness, functional pinch activity, no claw hand	negative/negative	negative/negative
10	numbness of the left little finger and ulnar side of ring finger, thenar muscle atrophy, claw hand, and contracture of the first web space	littile finger numbness, no claw hand, less contracture of the first web space	positive/positive or negative	positive/positive
11	numbness of the right little finger and ulnar side of ring finger, and hypothenar muscle atrophy	no numbness	negative/negative	negative/negative
12	numbness of the right little finger, ring finger and ulnar side of middle finger	no numbness	positive/negative	positive/negative
13	numbness of the right little finger and ulnar side of ring finger, pinch dysfunction, and claw hand	no numbness, functional pinch activity, no claw hand	positive/negative	positive/negative
14	right hand numbness and thenar muscle atrophy	no numbness	negative/negative	negative/negative
15	right hand numbness and thenar muscle atrophy	no numbness	negative/negative	negative/negative
16	right hand numbness and thenar muscle atrophy	no numbness	negative/negative	negative/negative

Fig. 3. Representative of finger adduction (A) and abduction (B) dysfunction, claw hand and thenar atrophy (C) in CuTS patients preoperatively.

compression sites and reused the thin sling of the medial muscular septum to create a tension-free double-strand helix loop as new and smooth channel for the nerve. Meanwhile, the anchoring at the residue of Osborne's ligament further strengthened the stability of the channel and reduced the likeliness of possible nerve subluxation. It was reported that the repair of the Osborne's ligament beneath the ulnar nerve in the modified Osborne's decompression reduced the nerve instability instead of simply dissecting and removing the Osborne's ligament [15]. We utilized the residue of this ligament for anchor positioning and enhanced the stability of the helix loop structure to support the nerve inside the loop channel. It is also less likely to kink during the rehabilitation. There are no obvious complications in this cases series after anterior nerve transposition. As for the demerits, it may increase the surgical time by this technique compared with other anterior transposition techniques or simple release.

In this study, the patients developed idiopathic CuTS or traumatic CuTS after peri-elbow fracture. The modified subcutaneous transposition technique is applicable to patients with over 10-year CuTS history and results in good outcomes at follow-ups. This is reflected in improvement in sensory examination and functional tests. In addition, the overall limb activity was improved to meet the demand for daily life. The bony deformity or soft tissue compression at different anatomical sites required us to perform a modified transposition technique instead of simple release to better improve and retain the good function of the ulnar nerve. From a direct view of ultrasound imaging, the bloodstream was limited and the synovium was thickened around the ulnar nerve in many patients preoperatively. This indicated the nerve compression and neuropathic edema. However, they were alleviated after the surgical release, transposition and protection of the affected ulnar nerve using helix sling technique. This technique did not cause new compression in the medial intermuscular septum channel. The general outcome was ideal because 14 out of 16 patients were freed from limb numbness at their final follow-ups.

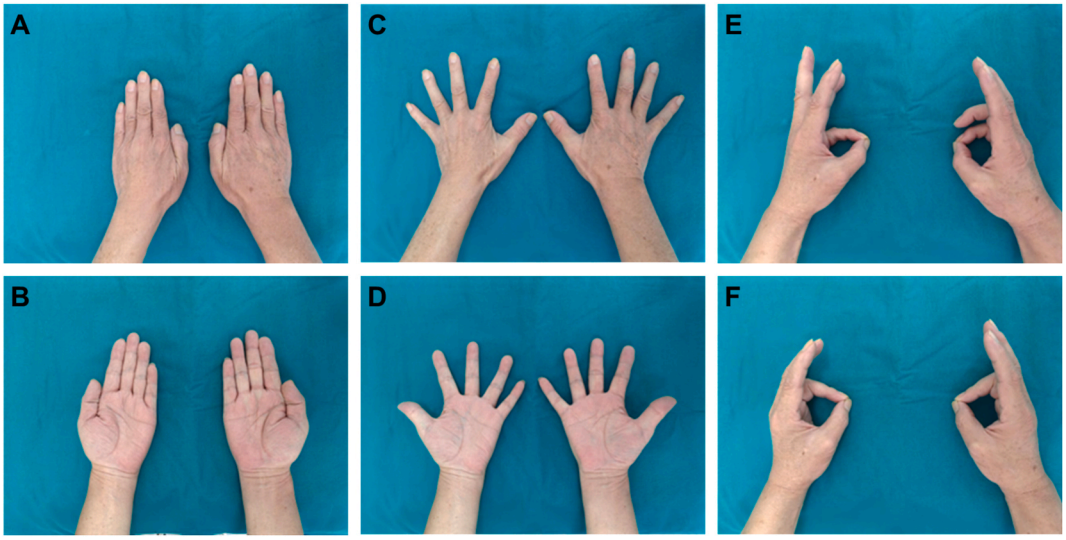

Fig. 4. Representative of functional finger adduction (A, B) and abduction (C, D) activity and little finger (E) and ring finger opposition function.

Table 3
Clinical scores related to pain and limb function, and ultrasound information.

Pre VAS	6.5 (3.5–8)
Final VAS	2 (1.5–4)
Pre quickDASH	45 (15.5–60.5)
Final quickDASH	21 (12.5–29)
Thickness diameter (preoperative) mm	4.5 (3–8.5)
Thickness diameter (postoperative) mm	3 (2.5–4.5)
Transverse diameter (preoperative) mm	9.5 (6–14.5)
Transverse diameter (postoperative) mm	5 (3–7.5)
Maximum cross-section area (preoperative) mm2	22 (13–31.5)
Maximum cross-section area (postoperative) mm2	12.5 (5–17.5)

VAS = visual analog scale.
quickDASH = quick Disabilities of the Arm, Shoulder, and Hand questionnaire.

There are several limitations of this study. First, this is a retrospective study and we did not apply randomization in the evaluation and grouping of the patients based upon the date of surgery. Thus, there is possible bias associated with patient selection. However, we may still obtain some promising findings by framing the research question appropriately in the non-randomized design [16]. The evaluation of nerve function was not blinded and the results were acquired from a small sample at a single center and therefore, it may yield limited statistical validity for evaluation. No difference existed in the patient composition of age and gender who were lost in follow-ups. However, it is still probable that they were different in postoperative radiographic or functional performances with participants in this study.

In conclusion, the medial intermuscular septum and Osborne's ligament is used to create a visible tension-free double-strand helix loop sling for stable and smooth sliding during subcutaneous ulnar nerve transposition, which is highly effective and safe for CuTS treatment in clinical practice.

Ethics approval

This study was approved by the Ethics Committee of Shanghai Sixth People's Hospital.

Patient consent

The patients provided informed consent for the use of their clinical data and images for publication and presentation.

Data availability statement

Data associated with this study was not deposited into a publicly available repository. Data will be made available on reasonable request.

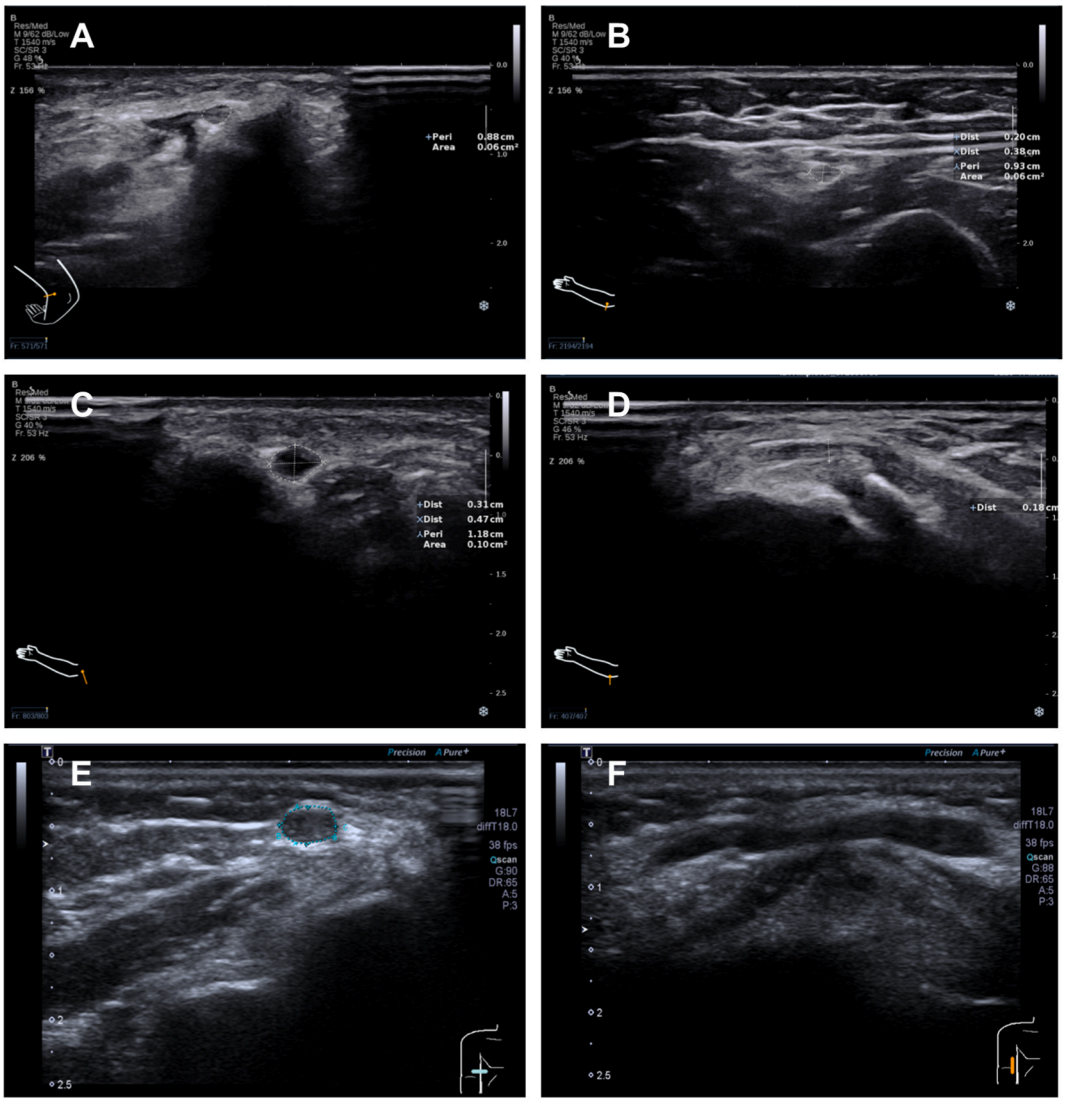

Fig. 5. Ultrasound imaging showing the ulnar nerve (A) at the forearm below the cubital tunnel, (B) at the forearm above the cubital tunnel, (C) at the upper arm (transverse section), and (D) at the upper arm (longitudinal section) preoperatively. (E) At the elbow (transverse section), and (F) at the elbow (longitudinal section) postoperatively.

Reporting sex- and gender-based analyses (SGBA)

We state that definitions of sex and/or gender we are applying to enhance the precision, rigor and reproducibility of our research and to avoid ambiguity or conflation of terms and the constructs to which we refer, were in accordance to Sex and Gender Equity in Research (SAGER) guidelines and the SAGER guidelines checklist.

CRediT authorship contribution statement

Yun Qian: Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Bingbo Bao:** Software, Methodology, Investigation, Formal analysis, Data curation. **Jiabao Wei:** Software, Methodology, Investigation, Formal analysis, Data curation. **Jialin Song:** Writing – review & editing, Validation, Project administration, Methodology, Investigation, Conceptualization. **Xianyou Zheng:** Writing – review & editing, Supervision, Project administration, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e25177.

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