



## Review article

## Ulnar neuropathy at the elbow

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## ABSTRACT

At the elbow, the ulnar nerve (UN) may be the site of a static compression (by the cubital tunnel retinaculum and Osborne's ligament between the two heads of the flexor carpi ulnaris), or a dynamic compression, especially when the nerve is unstable (subluxation/dislocation outside the ulnar groove). The clinical basis for the diagnosis of ulnar neuropathy involves looking for subjective and objective signs of sensory and/or motor deficit in the ulnar nerve's territory in the hand, a pseudo-Tinel's sign, and doing manipulations to provoke UN irritation. The diagnosis is confirmed by electromyography and ultrasonography. In the early stages, patient education and elimination of flexion postures or repeated elbow flexion motions can provide relief. If this fails or signs of sensory and/or motor deficit are present, surgical treatment is proposed. If the nerve is stable, in-situ nerve decompression is typically done as the first-line treatment. If the nerve is unstable, anterior nerve transposition – generally subcutaneous – or more rarely, a medial epicondylectomy can be done. If surgical treatment fails, the patient's history is reviewed, and diagnostic tests can be repeated. Except in cases of a fibrotic scar, the main causes of failure are neuroma of a branch of the medial cutaneous nerve of the forearm, instability of the nerve and persistence of a compression point. In the latter two cases, surgical revision is justified and anterior nerve transposition or epicondylectomy can be proposed.

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## 1. Introduction

Compression of the ulnar nerve (UN) at the elbow is the second most common entrapment neuropathy of the upper limb, after carpal tunnel syndrome, with an annual incidence of 21–25 cases/100,000 inhabitants in France. The UN is a mixed nerve arising from the C8–T1 roots of the brachial plexus, then the inferior trunk. Proximally to distally, it innervates the flexor carpi ulnaris (FCU), flexor digitorum profundus to the 4th and 5th fingers, abductor digiti minimi and opponens digiti minimi, palmar and dorsal interossei, 3rd and 4th lumbricals, adductor pollicis and deep head of the flexor pollicis brevis muscle. Its sensory territory consists of the ulnar side of the hand, anterior and posterior aspects of the 5th finger and ulnar half of the 4th finger.

At the elbow, it passes through an anatomical outlet located between the triceps brachii and the medial intermuscular septum, then under the cubital tunnel retinaculum (CTR) and finally under Osborne ligament's, between the two heads of the FCU. It can be compressed at multiple sites along this course.

We will aim to answer the following questions in this lecture:

- What are the causes of UN injury at the elbow?
- Which clinical and diagnostic tests need to be done when UN compression at the elbow is suspected?
- What is the role of conservative treatment?
- Which surgical techniques can be used and what are their indications and results?
- What are the options when surgical and non-surgical treatments fail?

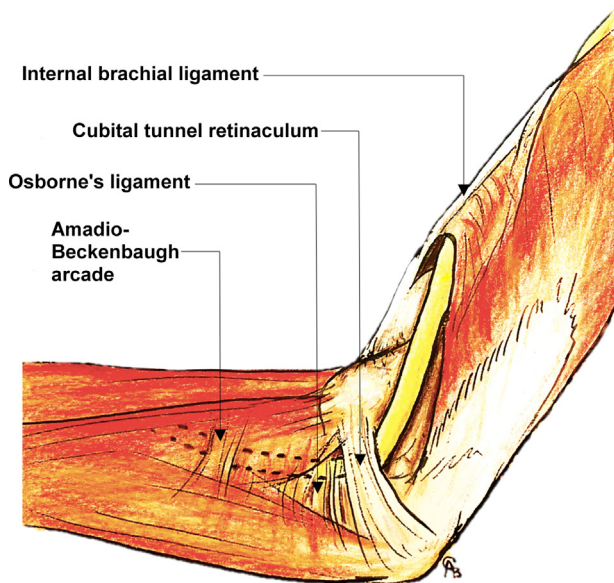
## 2. What are the causes of UN injury at the elbow?

## 2.1. Static, dynamic and acquired compression

## 2.1.1. Static compression

At the exit of the axillary fossa, the UN travels in the medial bicipital groove before it crosses the medial intermuscular septum, and enters the posterior compartment of the arm at a variable level. The medial margin of the septum can form a fibrous band called the internal brachial ligament, described by John Struthers, a 19th century Scottish anatomist and surgeon [1]. The nerve courses in the buttonhole, formed by this internal brachial ligament (arcade

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**Fig. 1.** Drawing of the anatomical structures that could compress the ulnar nerve at the elbow.

of Struthers) laterally and superiorly, and the medial intermuscular septum medially. This ligament is an insertion for fibres of the triceps brachii muscle, among others (Fig. 1).

The ligament of Struthers, which extends between the supracondylar process – a rare bony outgrowth on the anteromedial side of the distal humerus – and the distal medial humeral pillar does not contribute to compression. As for Struthers' arcade, first mentioned by Kane, Kaplan and Spinner, it turns out this was a dissection artefact, as it was not found in multiple subsequent anatomical studies [2]. This term should not be used, along with the incorrect image in the original publication. The UN descends into the posterior compartment of the upper arm between the septum and the triceps brachii muscle; hypertrophy of the latter may cause compression, especially in some athletes (weightlifters, baseball players).

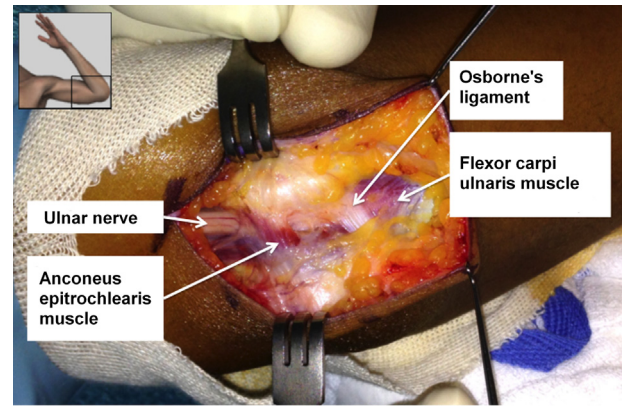
Behind the medial epicondyle of humerus, the nerve goes into the ulnar groove, which is the main site of UN compression. Its floor consists of the humeroulnar joint capsule and the posterior band of the medial collateral ligament, while its roof is formed by the CTR. This structure was classified into four types by O'Driscoll [3]:

- type 0: no CTR, such that the nerve is not stabilised in the groove and can dislocate forward during elbow flexion;
- type Ia: the CTR is normal, lax in extension and taut in full flexion;
- type Ib: CTR is thickened and contributes to compression;
- type II: the CTR is replaced by an accessory muscle, the anconeus epitrochlearis, which can cause compression due to its bulk (Fig. 2).

Where it exits the groove, the UN passes between the two heads (humeral and ulnar) of the FCU, joined by a fascia. Proximal thickening of the latter is called Osborne's ligament. When taut in flexion, it can compress the nerve. More distally, the Amadio-Beckenbaugh arcade, which extends between the humeral head of the FCU and the flexor digitorum superficialis, is the last potentially compressive structure [4] in the elbow area, although it is not consistently present (44% of cases).

### 2.1.2. Dynamic compression

During elbow flexion, the distance between the medial epicondyle of humerus and the olecranon increases, which places



**Fig. 2.** Anconeus epitrochlearis muscle located above Osborne's ligament that is particularly thick.

tension on the CTR and consequently reduces the diameter of the ulnar canal by about 55% [5,6]. The pressure increases even more when the FCU is contracted, reaching 205 mmHg in cases of ulnar tunnel syndrome. In addition, the nerve is stretched by an average of 4.7 mm. Together, these explain why any element, that stops the nerve's physiological gliding, increases the pressure inside the canal or stretches the nerve and leads to nerve damage. This is manifested by edema, which contributes to ischemia, which itself increases the edema. This vicious circle is responsible over time for perineural fibrosis, segmental demyelination and Wallerian degeneration – structural alterations at the origin of nerve conduction problems.

Another cause of UN injury at the elbow is its dislocation or subluxation forward during elbow flexion, in case of CTR insufficiency and forward bulging of the triceps brachii. This phenomenon exists in 16% to 20% of individuals and can be detected clinically or with ultrasonography [7]. It is bilateral in 75% of subjects. Only a minority of these patients have symptoms, attributed to impingement with the medial epicondyle of humerus, due to rubbing and direct compression in the front.

Certain throwing sports, such as baseball, can also bring about laxity of the medial collateral ligament and ulnar neuropathy, because the nerve is stretched when valgus loads are placed on the elbow joint. Lastly, occupations with repeated flexion–extension or forced elbow flexion are known to have a high risk of developing ulnar neuropathy: UN entrapment neuropathy in the ulnar groove confirmed by electroneuromyography is part of the picture for 57 occupational diseases in the general social security system in France.

### 2.1.3. Acquired compression

This is related to:

- reduction in the canal's "container": malunion of distal humerus or proximal ulna, osteophytes, hypertrophied synovium associated with rheumatoid arthritis, osteochondromatosis, synovial cysts;
- increase in the canal's "content": benign tumours (schwannomas, lipomas), adenopathy, leprosy nodules, or humeral fracture plate located on the posterior aspect of the medial condyle;
- increase in the length of the canal that stretches the nerve: cubitus valgus, because of distal humerus fracture or radial head resection, for example;
- systemic disease, such as diabetes.

**In summary**

The main causes of ulnar neuropathy at the elbow are:

- idiopathic neuropathy due to anatomical variation causing compression;
- pathological reduction in the ulnar groove's volume;
- excessive loading induced by certain postures or movements.

### 3. Which clinical and diagnostic tests need to be done when UN compression at the elbow is suspected?

#### 3.1. Clinical examination

##### 3.1.1. Functional signs

UN compression most often starts by paresthesia and dysesthesia of the last two fingers, especially at night, which is made worse by elbow flexion and repeated flexion–extension movements. The patient may also feel elbow pain that radiates towards the hand. At a more advanced stage, activities of daily living may be clumsy due to loss of strength in the hand's intrinsic muscles.

##### 3.1.2. Objective physical findings

The examination is bilateral and comparative. Upon inspection, one looks for atrophy of the first dorsal interossei muscles, visible between the metacarpals on the dorsum of the hand. In more advanced cases, there may be a claw deformity of the hand (extension of the metacarpophalangeal [MCP] joints with flexion of the proximal interphalangeal [PIP] joints, secondary to paralysis of the interossei muscles). This deformity mainly occurs in the ulnar-sided fingers because the median nerve innervates the radial lumbricals. The combination of claw deformity of the ulnar-sided fingers with atrophy of the interossei results in the appearance of a "Benediction hand".

The nerve's entire course is palpated to look for a potentially compressive mass. Nerve instability is determined by asking patients to flex and extend their elbow while palpating the nerve in the groove. One looks for hypoesthesia in the autonomous territory of the UN (tip of 5th finger and ulnodorsal side of hand). There may also be paresthesia of the muscles innervated by the UN [8]:

- flexor digitorum profundus to the 4th and 5th fingers, by the nail file maneuver with the PIP and DIP joints in maximum flexion;
- interossei muscles:
  - cross-finger test, which is positive when the patient is unable to cross the middle finger over the index finger,
  - evaluation of MCP flexion in segments when the PIP joints are extended,
  - Egawa's sign to test the lateral excursion of the middle finger, hands flat on a table. This can be measured and compared to the opposite side,
  - Wartenberg sign: constant abduction position of the 5th ray due to imbalance between the adducting forces of the MCP (interossei of 4th intermetacarpal space and extensor digitorum, most often spindly) and the abducting forces (extensor digiti minimi);
- muscles of the first web space:
  - deficit in active abduction in the index finger, ulnar side of hand placed on table due to deficit in the first dorsal interosseous muscle,
  - Froment's sign, which is searched by asking the patient to hold a piece of paper between the thumb and the radial side of the index finger: deficit in adductor pollicis and deep head of the

flexor pollicis brevis is responsible for loss of flexion strength of the thumb MCP, which is compensated by flexion of the thumb's IP joint, resulting from the contraction of the flexor pollicis longus muscle. If the UN fully innervates the flexor pollicis brevis, Froment's sign is increased and the thumb MCP will become extended or hyperextended during thumb-finger pinch grip, which is Jeanne's sign,

- palsy of the adductor pollicis and dorsal interosseous muscles is responsible for weakness during pinch grips that can be measured with a pinch gauge.

The McGowan classification (modified by Goldberg) differentiates between minor conditions (grade 1) with intermittent paresthesia and discrete hypoesthesia without motor deficit, intermediate conditions (grade 2) with permanent sensory deficit, strength loss and early atrophy, and severe conditions (grade 3) with marked atrophy and significant weakness of the hand's intrinsic muscles [9].

##### 3.1.3. Provocative testing

In entrapment neuropathy, the damaged nerve is more sensitive to direct stimulation or stretching at the compression site, which provokes paresthesia in its territory:

- the elbow flexion test, or Phalen elbow test, is done with the elbow in maximum flexion; its sensitivity is increased by shoulder abduction and wrist extension [10]; it is positive when it reproduces or aggravates the pain in less than 30 seconds; its specificity is low;
- a pseudo Tinel's sign can be detected at the various sites of potential compression: ulnar groove, FCU;
- the scratch collapse test, which is a newer test, consists in asking the patient to perform shoulder external rotation while resisting pressure applied on the outside of both forearms, elbows against the body and flexed 90°, on two occasions, separated by lightly touching the nerve at the elbow [11]. Brief loss of the ability to resist the examiner is interpreted as confirmation of the nerve's compression site.

##### 3.1.4. Differential diagnosis

The physical exam ends with a complete neurological examination of the upper limbs, specifically to look for signs of UN compression in Guyon's canal, thoracic outlet syndrome (symptoms triggered by raising the arm, Roos maneuver, Chalmers maneuver, pseudo Tinel's sign with tapping of the supraclavicular fossa), cervicobrachial neuralgia (paresthesia in the C8–T1 territory, but not the ulnar trunk territory, neck pain). Lastly, one looks for other associated musculoskeletal disorders, such as medial or lateral epicondylar pain; these symptoms may be suggestive of atypical ulnar neuropathy [12].

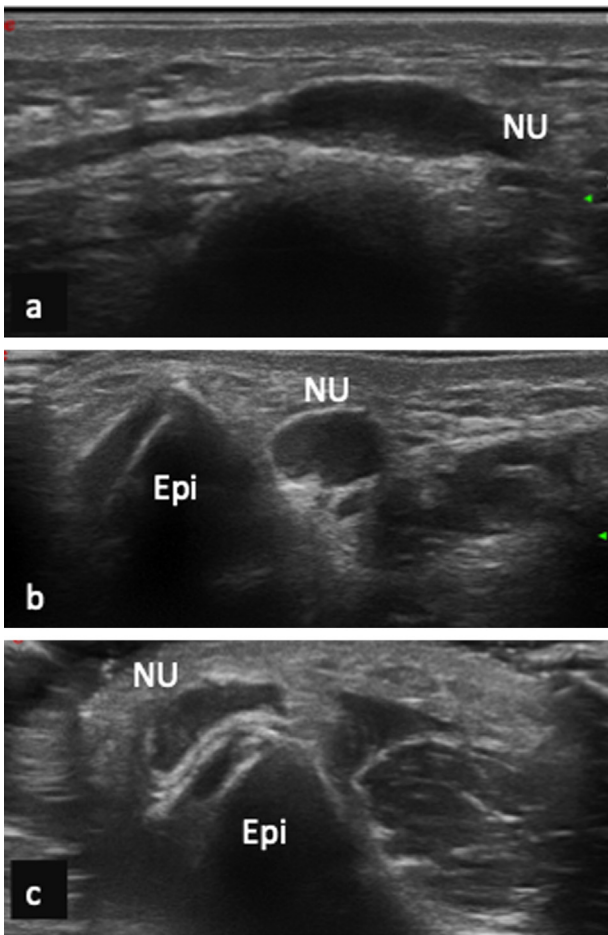
#### 3.2. Additional examinations

##### 3.2.1. Electromyogram (EMG)

EMG is useful for confirming the diagnosis, ruling out other differential diagnoses, looking for double-crush syndrome and evaluating the prognosis. In fact, conduction speed is correlated to the severity of the condition. It has a medicolegal benefit, justifying a surgical indication, and by serving as a reference examination if the results are not satisfactory.

First, EMG is used to study the sensory and motor conduction speeds (normal about 50 m/s) and to view the number and extent of motor unit activity in the abductor digiti minimi and first dorsal interosseous muscles.

In detection mode, it looks for signs of spontaneous muscle activity as a sign of chronic denervation. It can detect motor



**Fig. 3.** Ultrasonography images of an ulnar nerve with larger volume in the groove on a sagittal view (a) and axial view (b), which dislocates to the other side of the apex of the medial epicondyle of humerus during elbow flexion (c). Images provided by Dr A. Miquel.

conduction deficits at the elbow and reduced amplitude of the sensory potential of the little finger.

### 3.2.2. Ultrasonography

Ultrasonography is the preferred modality as it can analyse the UN statically and dynamically. It must be bilateral and comparative. The normal appearance of the UN on a longitudinal view is that of a tube, made up of parallel hypoechoic fascicles separated by hyperechoic lines corresponding to epi- and perineural structures. On a transverse view, the nerve is nearly oval, but is more rounded upstream of the ulnar groove, flattened under the CTR – especially when the elbow is flexed – and between the two heads of the FCU. The mean cross-sectional area (CSA) upstream of the ulnar tunnel ranges from 6.6 to 7.9 mm<sup>2</sup> [13]. In the groove, the fascicles are not as well differentiated.

The main signs of chronic nerve damage are an increase in its axial CSA due to edema directly upstream of the compressive zone, by about 10 mm<sup>2</sup>, and a loss in the fascicular appearance and intra- and perineural hypervascularity in Doppler mode [14]. Dynamic elbow maneuvers are done to help look for abnormal motion or instability of the nerve in flexion (Fig. 3).

Ultrasonography contributes to identifying the etiology because it provides a refined analysis of bone, tendon and joint structures. Lastly, it helps to evaluate the prognosis since the nerve's diameter is directly related to the severity of the condition.

### 3.2.3. Radiographs

Conventional radiography includes AP and lateral views and elbow acute flexion AP view (AP view of the elbow in maximum flexion and 15° external rotation). These are used to look for elbow misalignment, arthritic or post-traumatic bone abnormalities (malunion, non-union of the medial epicondyle), osteochondromatosis.

### 3.2.4. MRI

MRI of the elbow in extension is not a routine examination in a patient with suspected ulnar neuropathy, but it is necessary when there is a doubt about an expansive mass due to tumour, muscle or tendon over the nerve's trajectory, or when there is a failure or recurrence after surgical treatment [15]. Nerve compression manifests itself as an elevated T2-weighted signal, which must be carefully interpreted given that this finding is present in 60% of asymptomatic subjects, along with an increase in the signal in the muscles innervated by the UN on STIR sequences (elimination of fat signal), indicative of their denervation.

#### In summary

The diagnosis of UN entrapment is generally based on a range of arguments:

- clinical (subjective and objective neurological deficits, positive provocative tests);
- ultrasonography;
- and EMG.

## 4. What is the role of conservative treatment?

The first is patient education: The patient must avoid doing repetitive motions and prolonged elbow hyperflexion during their personal life (intensive phone use) and professional life (adjustments to workstation). This can be supplemented by wearing an elbow splint at night at 30° of flexion. The few randomised controlled studies that have been done show that corticosteroid injections do not provide any clinical benefit or improve the EMG [16].

Conservative treatment is indicated in early UN conditions that are less than 6 months old, without motor or sensory deficit, i.e. patients who have minor UN compression symptoms at the elbow according to McGowan, especially when the EMG is normal.

Svernlöv compared three groups of patients who had light or moderate UN compression symptoms at the elbow; two groups received a treatment of 3 months' night-time splint that prevented the elbow from flexing more than 45°, or nerve gliding exercises consisting of alternating postures in different flexion positions [17]. All patients received written information about the pathology and the motions to avoid. The third group did not receive this information. At 6 months, the group who received a splint and self-directed rehabilitation did not have less night pain than the group who received only education. Daytime pain and patient satisfaction were improved more in the groups that received patient education only and self-directed rehabilitation than in the splint group. Lastly, in their 2016 meta-analysis, Caliandro et al. found no studies with a high level of evidence comparing conservative treatment to surgical treatment [18].

**In summary**

- No conservative treatment or orthotic device has been shown to be effective for treating ulnar neuropathy at the elbow.
- In its early stages, patient education and elimination of flexion postures and repeated elbow flexion can provide pain relief.

**5. Which surgical techniques can be used and what are their indications and results?**

Surgical treatment is indicated when the diagnosis is confirmed by a good match between clinical findings and diagnostic tests, and when conservative treatment has failed or is not appropriate due to sensory or motor deficits. The three most used techniques, in order of frequency, are in situ nerve decompression, anterior transposition and medial epicondylectomy. In all instances, the patient is typically operated with regional anesthesia. With the patient supine, the upper limb is placed on an arm board and a tourniquet placed proximally. The shoulder is externally rotated, and the elbow flexed and elevated.

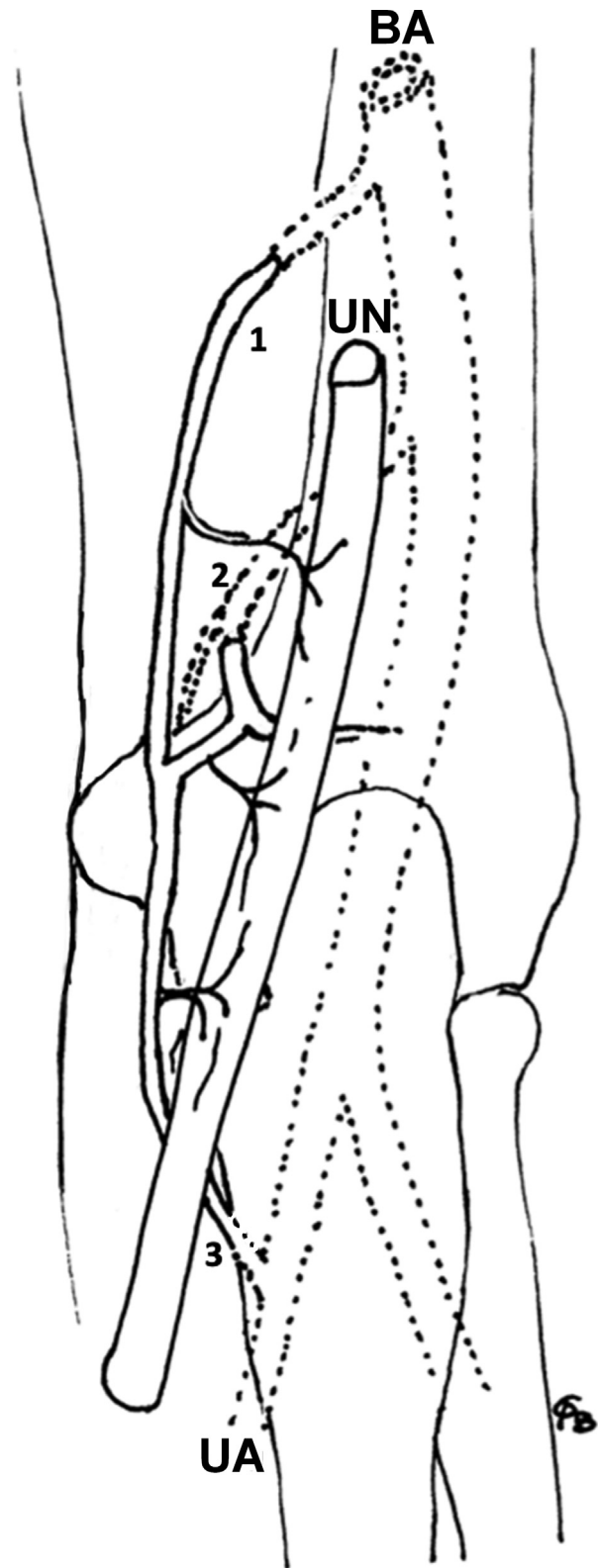
Certain technical principles are common to all open procedures:

- the main objective is to verify and release all the potential nerve compression sites, from proximal to distal, which in practice is about 15 cm;
- no matter which procedure is done, careful hemostasis is essential, potentially after releasing the tourniquet at the end of the surgery, given the presence of the peri-articular arterial anastomosis at the elbow. Around the medial epicondyle of humerus, this results in anastomosis of two anterior and posterior branches of the inferior ulnar collateral artery stemming from the brachial artery, with the anterior and posterior ulnar recurrent arteries. These arteries participate in vascularisation of the ulnar nerve, particularly the superior collateral ulnar artery, which should be preserved, to limit the devascularisation of the nerve especially during a transposition procedure (Fig. 4);
- lastly, the postoperative course does not generally require elbow immobilisation; this allows a gliding plane to reform around the nerve. In fact, adhesions of a decompressed or transposed nerve with the neighbouring tissues can lead to failure.

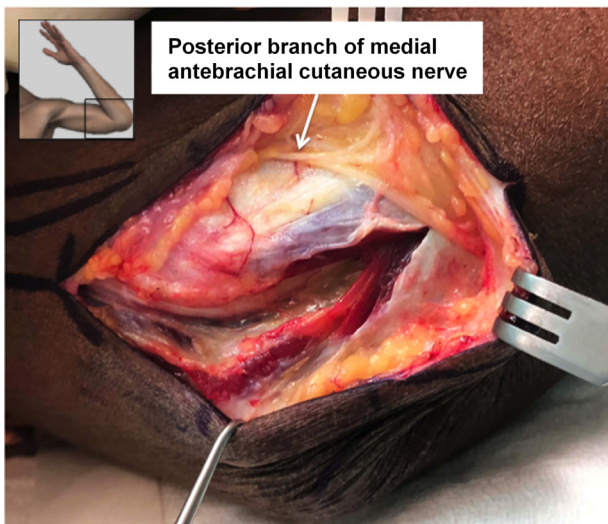
**5.1. In-situ nerve decompression**

This consists of proximal to distal release of all structures that could potentially compress the UN at the elbow: internal brachial ligament, CTR, Osborne's ligament, and the Amadio-Beckenbaugh arcade.

The surgical approach comprises a superior vertical branch parallel to the upper arm's axis, starting behind the medial epicondyle of humerus and an inferior branch parallel to the forearm axis. Thus, it follows the nerve's trajectory. It must be long enough to provide access to all the potential compression points. It is vital to protect the cutaneous sensory nerve branches and especially the posterior branch of the medial cutaneous nerve of the forearm, which crosses the lower portion of the incision (Fig. 5) [19]. Lesions of these branches are responsible for 90% of cases of postoperative pain [20]. The CTR and Osborne's ligament are transected. The nerve does not need to be completely lifted from its bed, as this might induce nerve instability (subluxation in flexion) and might stretch its motor branches emanating from the deep side. Lastly,



**Fig. 4.** Arterial vascularisation of the ulnar nerve in the distal portion of the upper arm and the upper portion of the forearm (dorsal view). This vascular network varies. BA: brachial artery, UA: ulnar nerve, UA: ulnar artery, 1: superior ulnar collateral artery, 2: inferior ulnar collateral artery, 3: ulnar recurrent artery (posterior branch).



**Fig. 5.** In-situ nerve decompression showing the proximity of the branches of the medial cutaneous antebrachial nerve.

nerve stability in its groove is tested with the elbow flexed. In the postoperative course, the patient can immediately move the elbow.

The simplicity and low morbidity of in situ nerve decompression make this the preferred technique for patients without nerve instability [21].

### 5.2. Endoscopic nerve decompression

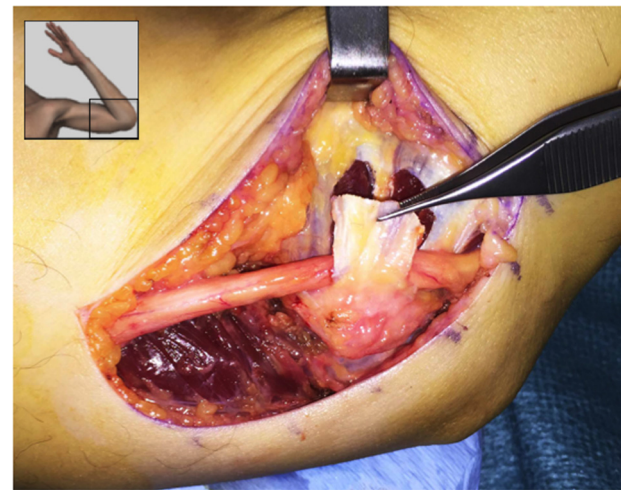
Recently described [22], this technique aims to reduce the consequences of the skin incision, reduce the risk of postoperative complications, and allow earlier return to work. It requires an endoscope, a light source, speculum of appropriate size, like the ones used in ORL surgery, and long thin blunt scissors. The principle is to make a short incision over the groove, to open the CTR and then to create a working space between the hypodermis and the brachial fascia proximally, the antebrachial fascia distally, making sure not to damage any of the cutaneous sensory branches or veins. The speculum is placed in this space and acts as a retractor. Osborne's ligament is cut, along with any fibrous bands joining the two FCU heads up to about 10 cm under the CTR. On the upper side, the brachial fascia and any internal brachial ligaments are transected, but not the medial intermuscular septum. In the postoperative course, it is recommended that the patient avoid elbow flexion for 6 weeks.

This treatment is reserved for patients with intrinsic nerve compression where the nerve is clinically stable, no matter how advanced the disease. In a double blind prospective randomised study, Schmidt found no differences in the clinical outcomes or EMG between patients who underwent open nerve decompression and those who underwent endoscopic nerve decompression [23]. Conversely, the postoperative bleeding rate was significantly higher in the group who underwent endoscopic treatment.

### 5.3. Anterior transposition

This consists of shifting the UN so it passes in front of the medial epicondyle of humerus to shorten its course and eliminate its instability. It requires extensive release of the nerve both proximally and distally, so that its trajectory is as direct as possible and avoids any twists and turns, as this contributes to failure. The branches destined to the joints are also sacrificed.

Resection of the lower portion of the medial intermuscular septum is done, while doing careful hemostasis. In fact, the transverse



**Fig. 6.** Subcutaneous anterior transposition of the ulnar nerve. After resection of the lower portion of the medial intermuscular septum and distal release, the nerve passes in front of the medial epicondyle of humerus. For stabilisation, the fascial flap of the epitrochlear muscles is fixed on the deep side of the anterior margin of the incision.

arterial anastomosis between the posterior branch of the inferior ulnar collateral artery and the branches of the deep brachial artery is most often disrupted during this step. Distally, mobilisation of the nerve may require sacrifice of its first branch destined to the FCU.

The transposition is generally done in the subcutaneous space: The nerve is placed between the hypodermis and the epitrochlear muscles. It is stabilised using a newly created posterior septum made of a fascial flap from the epitrochlear muscles (Fig. 6) or from hypodermic fat, which is secured to the deep aspect of the anterior margin of the incision. More rarely, it can be positioned in a trench in the pronator teres and flexor carpi radialis muscles, or even under the medial epicondylar muscles. A Z-plasty is made in the muscles located above the flexor digitorum superficialis to produce lengthening.

In patients with distal humerus fracture, multiple studies have looked into whether the UN should be immediately transposed to prevent nerve damage due to contact with a posteromedial fracture fixation plate. It seems preferable to reserve the transposition to the cases of post-operative nerve compression [24].

### 5.4. Medial epicondylectomy

First described in 1950 by King [25], this technique consists in nerve decompression through the same approach as open nerve decompression, along with resection of the subperiosteal portion of the medial epicondyle. This results in slight anterior translation of the nerve and shortening of its course during elbow flexion. When done poorly, it can trigger elbow instability secondary to transection of the medial collateral ligament. In fact, its posterior and middle bundles insert on the anterior inferior and inferior side (respectively) of the base of the medial epicondyle, against the medial wall of the trochlea.

The procedure starts with subperiosteal exposure of the medial epicondyle after partial detachment of the epitrochlear muscles, then an osteotomy along a sagittal cut plane, angled slightly posteriorly and inwards, and removing approximately the superficial 2/3 of the medial epicondyle (Fig. 7). The periosteal and tendinous layers are carefully reclosed using reverse stitches and the nerve's trajectory is verified. Postoperatively, the upper limb is not immobilised. Reported complications are medial elbow pain in 15% to 50% of cases, generally for less than one year, and discomfort

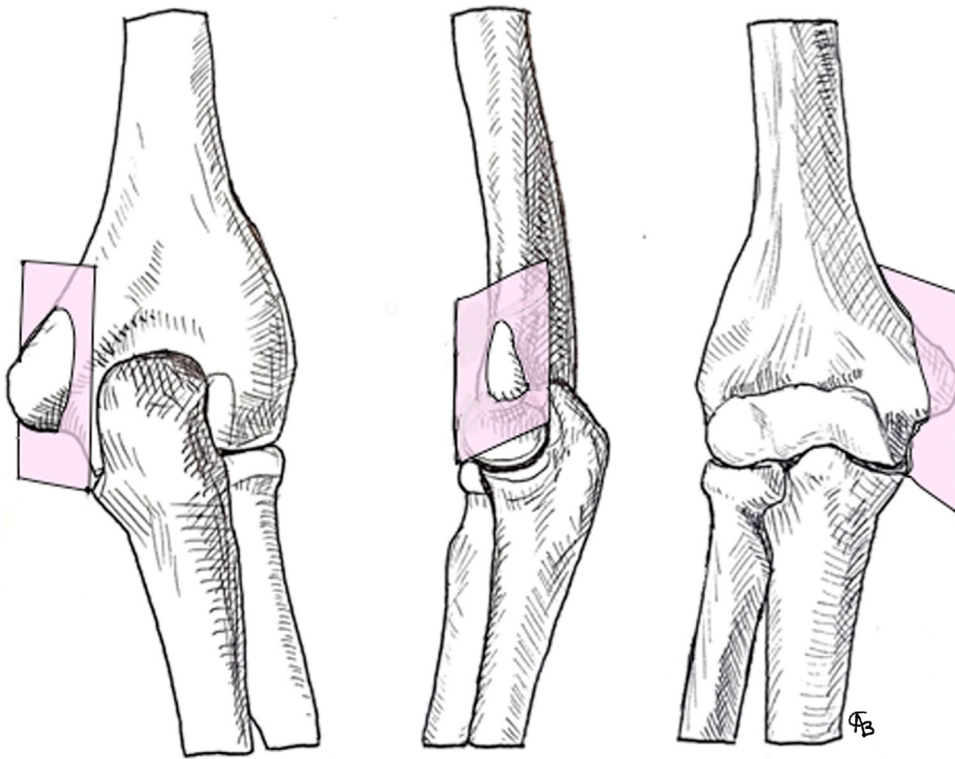


Fig. 7. Osteotomy cuts in the medial epicondylectomy. The base of the epicondyle is preserved to protect the medial collateral ligament.

during support because the bony process is no longer there. Partial frontal medial epicondylectomy is a technical variation where only the posterior portion of the medial epicondyle is removed, which simply makes the gutter deeper [26].

A small share of surgeons prefers using this procedure as their first-line technique. Its best indications are nerve instability or surgical revision after failure of in situ nerve decompression. In their meta-analysis of medial epicondylectomy studies, O'Grady found that 79% of patients had an improvement in their McGowan grade, while 83% had good or excellent outcomes [27]. In addition, the few studies in which medial epicondylectomy and in situ nerve decompression or anterior transposition were compared found similar or even better results after epicondylectomy [28].

While certain surgeons prefer doing anterior transposition as the first-line treatment, this procedure is generally recommended for cases of primary nerve instability or instability secondary to in situ nerve decompression, or when the groove is filled because of a joint-related pathology, or a valgus elbow deformity. Several meta-analyses found no difference in the clinical outcomes and EMG results between in situ nerve decompression and submuscular or subcutaneous transpositions [18]. In a prospective randomised study, Biggs et al. observed that patients who had a submuscular transposition had comparable results to those who underwent in situ nerve decompression (improvement in neurological status of 67% and 61%, respectively), but with more local complications such as surgical site infection [21].

## 6. What are the options when surgical and non-surgical treatments fail?

The first step is to review the patient's entire medical history and case history, rule out differential diagnoses, retrieve the operative report(s) and EMG findings, and determine whether postoperative immobilisation was done.

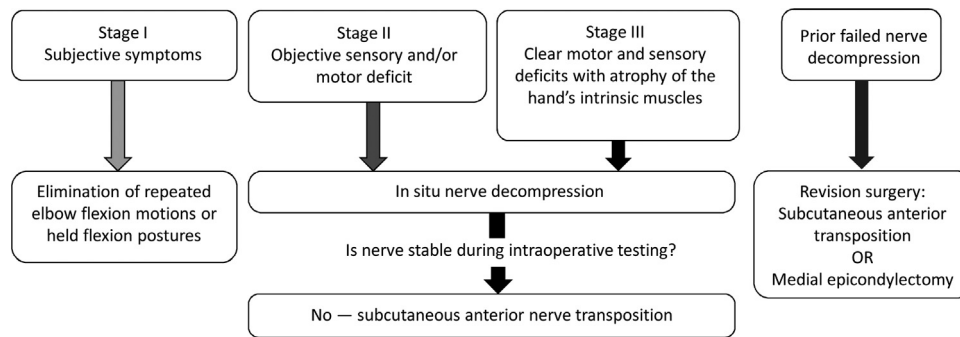
### In summary

- Contrary to carpal tunnel surgery, the results of ulnar nerve decompression at the elbow are not always predictable. Consequently, only the patients whose clinical diagnosis is confirmed by diagnostic tests should be treated surgically.
- Several precautions help to reduce the likelihood of complications and poor results: preserving the subcutaneous nerve branches, careful hemostasis, verification of the completeness of the nerve decompression and the absence of nerve instability at the end of the procedure.
- Currently, the literature has few prospective randomised studies that can be used to recommend one technique over the other. However, in situ nerve decompression is the most frequently used technique as it is simple and associated with fewer complications than transposition and medial epicondylectomy (Fig. 8).

Once the initial diagnosis is confirmed, the timing of the appearance of subjective and objective sensory and motor symptoms is defined: Persistence, or even worsening of symptoms without a symptom-free period in the immediate postoperative course or instead, reappearance? The type and location of the pain are identified.

The clinical examination is redone to look for deficits in the ulnar nerve and medial antebrachial cutaneous nerve territories. The nerve's stability is evaluated. The pseudo Tinel sign is detected over the nerve's path, which may help to precisely locate a persistent compression zone, especially at any bends in the new trajectory of the transposed nerve. Ultrasonography can also be used to identify any residual compressive areas. Direct communication with the radiologist is recommended. Lastly, an EMG can be prescribed, and its results compared to the one carried out preoperatively.

In a meta-analysis of surgical revisions for ulnar nerve decompression at the elbow, Kholinne observed that half the procedures



**Fig. 8.** Proposed decision algorithm for idiopathic ulnar nerve compression at the elbow, where the nerve is stable inside its groove. The stages are the same ones used in the McGowan classification as modified by Goldberg [9].

during the first intervention were anterior transposition [29]. The main intraoperative observation was fibrous scar encapsulation of the nerve. The most common site of residual compression was the medial intermuscular septum.

Based on this information, several scenarios are possible: Neuroma due to transection of the medial antebrachial cutaneous nerve, instability after in situ nerve decompression, persistence of a compressive zone. If there are clinical or imaging arguments in favour of these latter two situations, another nerve decompression procedure should be done, generally combined with anterior transposition or medial epicondylectomy.

The patient must be warned that the results of a revision surgery may be modest and are less predictable than those of primary surgery: Van Gent et al. found only 35% improvement in pain and paresthesia in the postoperative course of anterior transposition done as the second-line treatment after failure or in situ nerve decompression [30]. However, 65% of patients felt they had good results, especially the younger patients in the cohort. Saris et al. showed that in patients who had a medial antebrachial cutaneous neuroma discovered during the revision procedure, the results were less good, despite excision and burying of the nerve [31].

#### In summary

- Failure of surgical treatment for ulnar neuropathy at the elbow must trigger an “investigated” clinical examination and diagnostic tests.
- Reduction in symptoms after revision of the ulnar nerve decompression is unpredictable and regularly modest.
- The best indications for surgical revision are likely instability after nerve decompression and persistence of a compressive area, confirmed with ultrasonography.
- The preferred techniques are anterior nerve transposition and medial epicondylectomy.

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The authors declare that they have no competing interest.

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#### Author contributions

Adeline Cambon-Binder is author and reviewer of manuscript.

#### 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.2020.102754>.

#### References

- [1] Struthers J. On some point in the abnormal anatomy of the arm. *Br Foreign Med Chir Rev* 1854;13:523–33.
- [2] De Jesus R, Dellon AL. Historic origin of the “Arcade of Struthers”. *J Hand Surg Am* 2003;28:528–31.
- [3] O’Driscoll SW, Horii E, Carmichael SW, Morrey BF. The cubital tunnel and ulnar neuropathy. *J Bone Joint Surg Br* 1991;73:613–7.
- [4] Amadio PC, Beckenbaugh RD. Entrapment of the ulnar nerve by the deep flexor–pronator aponeurosis. *J Hand Surg* 1986;11A:83–7.
- [5] Apfelberg G, Larson SJ. Dynamic anatomy of the ulnar nerve at the elbow. *Plastic Rec Surg* 1973;51:81.
- [6] Schuind FA, Goldschmidt D, Bastin C, Burny F. A biomechanical study of the ulnar nerve at the elbow. *J Bone Joint Surg* 1995;20B:623–7.
- [7] Rutter M, Grandzio LC, Malone WJ, Klena JC. The use of preoperative dynamic ultrasound to predict ulnar nerve stability following in situ decompression for cubital tunnel syndrome. *J Hand Surg* 2019;44:35–8.
- [8] Goldman SB, Brininger TL, Schrader JW, Curtis R, Kocaja DM. Analysis of clinical motor testing for adult patients with diagnosed ulnar neuropathy at the elbow. *Arch Phys Med Rehabil* 2009;90:1846–52.
- [9] Goldberg BJ, Light TR, Blair SJ. Ulnar neuropathy at the elbow: results of medial epicondylectomy. *J Hand Surg* 1989;14A:182–8.
- [10] Novak CB, Lee GW, Mackinnon SE, Lay L. Provocative testing for cubital tunnel syndrome. *J Hand Surg* 1994;19A:817–20.
- [11] Cheng CJ, Mackinnon-Patterson B, Beck JL, Mackinnon SE. Scratch collapse test for evaluation of carpal and cubital tunnel syndrome. *J Hand Surg* 2008;33A:1518–24.
- [12] Pellieux S, Fouquet B, Lasfargues G. Syndrome du nerf ulnaire au coude et maladie professionnelle. Analyse des paramètres socioprofessionnels et physiques. *Ann Readapt Med Phys* 2001;44:213–20.
- [13] Jacob D, Creteur V, Courthaliac C, Bargoin R, Sassus B, Bacq C, et al. Sonoanatomy of the ulnar nerve in the cubital tunnel: a multicentre study by the GEL. *Eur Radiol* 2004;14:1770–3.
- [14] Okamoto M, Abe M, Shirai H, Ueda N. Diagnostic ultrasonography of the ulnar nerve in cubital tunnel syndrome. *J Hand Surg* 2000;25A:499–502.
- [15] Drapé JL, Cotten A, Chevrot A. Intérêt de l’IRM dans les syndromes canauxiers du membre supérieur. *Chir Main* 2004;23S1:15–26.
- [16] Hong CZ, Long HA, Kanakamedala RV, Chang YM, Yates L. Splinting and local steroid injection for the treatment of ulnar neuropathy at the elbow: clinical and electrophysiological evaluation. *Med Rehabil* 1996;77:573–7.
- [17] Svernlöv B, Larsson M, Rehn K, Adolfsson L. Conservative treatment of the cubital tunnel syndrome. *J Hand Surg Eur Vol* 2009;34:201–7.
- [18] Caliandro P, La Torre G, Padua R, Giannini F, Padua L. Treatment for ulnar neuropathy at the elbow. *Cochrane Database Syst Rev* 2016;11:CD006839.
- [19] Dellon AL, MacKinnon SE. Injury to the medial antebrachial cutaneous nerve during cubital tunnel surgery. *J Hand Surg* 1985;10B:33–6.
- [20] Jackson LC, Hotchkiss RN. Cubital tunnel surgery. Complications and treatment of failures. *Hand Clin* 1996;12:449–56.
- [21] Biggs M, Curtis JA. Randomised, prospective study comparing ulnar neurolysis in situ with submuscular transposition. *Neurosurgery* 2006;58:296–304.
- [22] Hoffmann R, Siemionow M. The endoscopic management of cubital tunnel syndrome. *J Hand Surg* 2006;31B:23–9.
- [23] Schmidt S, Kleist Welch-Guerra W, Matthes M, Baldauf J, Schminke U, Schroeder HW. Endoscopic vs. open decompression of the ulnar nerve in cubital tunnel syndrome: a prospective randomised double-blind study. *Neurosurgery* 2015;77:960–70.
- [24] Shearin JW, Chapman TR, Miller A, Ilyas AM. Ulnar nerve management with distal humerus fracture fixation: a meta-analysis. *Hand Clin* 2018;34:97–103.

- [25] King T. The treatment of traumatic ulnar neuritis; mobilisation of the ulnar nerve at the elbow by removal of the medial epicondyle and adjacent bone. *Aust N Z J Surg* 1950;20:33–42.
- [26] Efsthathopoulos 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;444:134–9.
- [27] O'Grady EE, Vanat Q, Power DM, Tan S. A systematic review of medial epicondylectomy as a surgical treatment for cubital tunnel syndrome. *J Hand Surg Eur Vol* 2017;42:941–5.
- [28] 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* 1996;78B:777–9.
- [29] Kholinne E, Alsharidah MM, Almutair O, Aljasser S, Alhothali W, Kwak JM, et al. Revision surgery for refractory cubital tunnel syndrome: a systematic review. *Orthop Traumatol Surg Res* 2019;105:867–76.
- [30] van Gent JA, Datema M, Groen JL, Pondaag W, Eekhof JL, Malessy MJ. Anterior subcutaneous transposition for persistent ulnar neuropathy after neurolysis. *Neurosurg Focus* 2017;42:E8.
- [31] Sarris I, Göbel F, Gainer M, Vardakas DG, Vogt MT, Sotereanos DG. Medial brachial and ante-brachial cutaneous nerve injuries: effect on outcome in revision cubital tunnel surgery. *J Reconstr Microsurg* 2002;188:665–70.