# Ultrasound of the Ulnar Nerve: A Pictorial Review

## Part 2: Pathological Ultrasound Findings

*Marco Becciolini, MD, Christopher Pivec, MD, Andrea Raspanti, MD, Georg Riegler, MD*

This is the second part of a two-part article in which we focus on the ultrasound (US) appearance of the pathological ulnar nerve (UN) and its main branches. Findings in a wide range of our pathological cases are presented with high-resolution US images obtained with the latest-generation US machines and transducers.

*Key Words*—cubital tunnel; entrapment; Guyon; Struthers arcade; ulnar nerve

This is the second part of a two-part article in which we review the ultrasound (US) findings in cases of pathology of the ulnar nerve (UN) and its main branches.[1]

We briefly describe the clinical presentations of UN disorders.

Furthermore, we present a wide range of pathological cases, not only at the cubital tunnel where the nerve is commonly entrapped.

The article is intended to help clinicians interested in musculoskeletal US and, particularly, in nerve US since we have not found a recent review in the literature that covers in detail the US appearance of UN pathology.

The IRB waived the necessity to obtain informed consent for this study.

### *Concise Summary of Clinical Presentations in UN Neuropathies*

The cubital tunnel and the Guyon's canal are the usual sites of UN entrapment.

The cubital tunnel is an osteofibrous tunnel in the retro-epicondylar area of the elbow.[1]

Cubital tunnel syndrome at the elbow is the second most common compressive neuropathy of the upper limb, after carpal tunnel syndrome.[2] Patients may experience sensory and motor disorders. Most frequently, patients initially complain of paresthesia of the fifth finger and the ulnar aspect of the fourth finger. Pain at the medial elbow may be associated. Intrinsic hand muscle weakness related to a motor deficit may be also observed at presentation. Patients may present with clawing of the ring and little fingers related to paralysis of both lumbricals and interossei muscles (Figure 1). Clinical examination includes the Tinel test at the level of the cubital tunnel. Wartenberg's sign refers to the ulnar deviation of the little finger, while Froment's sign is related to compensation in key pinch

Cover image article

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*Address correspondence to Marco Becciolini, Misericordia di Pistoia, Via Bonellina 1, Pistoia 51100, Italy.*

*E-mail:* marcobecciolini@gmail.com

**Abbreviations**

*CSA, cross-sectional area; DBUN, deep branch of the ulnar nerve; DCBUN, dorsal cutaneous branch of the ulnar nerve; FCU, flexor carpi ulnaris; pbUCL, posterior band of the ulnar collateral ligament; SBUN, superficial branch of the ulnar nerve; UN, ulnar nerve; US, ultrasound*

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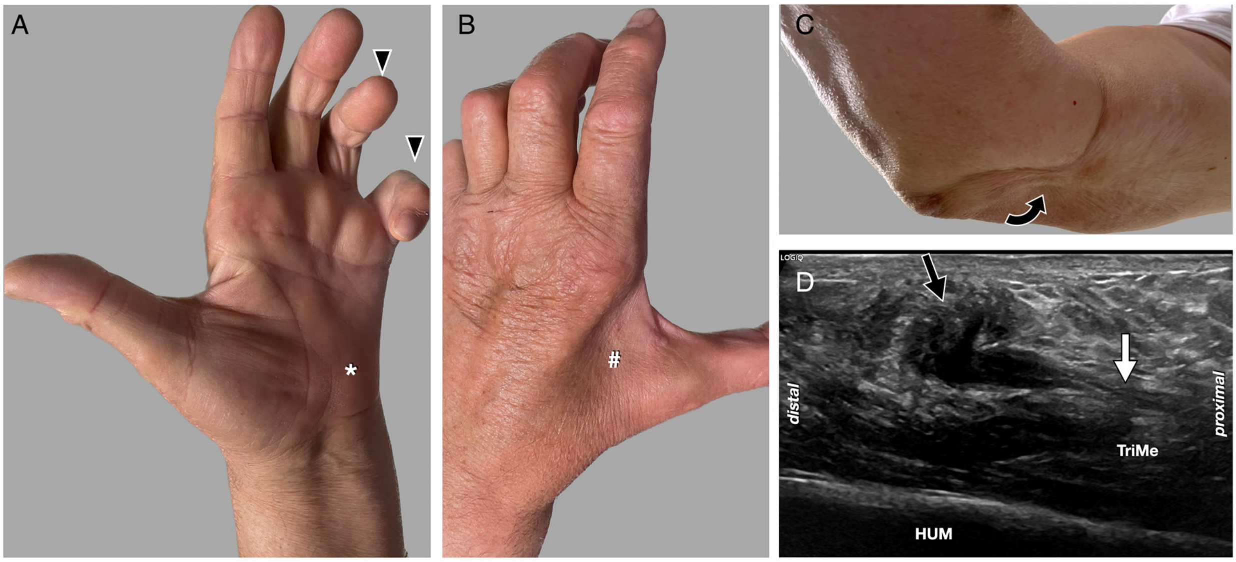
**Figure 1.** Clinical presentation in severe chronic UN neuropathy. Amputation neuroma in a patient with a previous laceration injury proximal to the elbow. In **A**, note atrophy of the hypothenar muscles (asterisk). The ring and mainly the little finger are flexed (clawing hand, black arrowhead) due to interosseus and lumbrical palsy. The little finger is a bit abducted (Wartenberg's sign). **B**, There is atrophy of the interossei muscles and particularly of the first dorsal interosseous (#). In **C**, proximal to the elbow, the scar of a previous laceration is clinically evident (black curved arrow). **D**, Corresponding long-axis of the UN (white arrow) at the level of the laceration, where an amputation neuroma (black arrow) can be demonstrated. HUM indicates the humerus; TriMe, medial head of the triceps.




weakness: in fact, patients pinch by flexion of the interphalangeal joint of the thumb.[3]

Guyon's canal syndrome is a rarer UN neuropathy involving the nerve at the level of the wrist. Shea and McClain, and later, Gross and Gelberman classified three specific types of UN nerve compression syndrome, related to the zone of the disease.[4,5] In zone I, the UN is compressed proximally or within the canal, leading to sensory and motor alterations. In zone II, only the deep branch of the UN (DBUN) is compressed. In zone III, only the superficial branch of the UN (SBUN) is affected with no motor deficit.[4,5] Zone I entrapment may be challenging to distinguish from proximal neuropathy; however, they can be differentiated because the dorsal ulnar surface of the hand is not involved in the former case, due to sparing of the dorsal cutaneous branch of the UN (DCBUN), which arises around 6 cm proximal to the ulna styloid.[6–9] Moreover, the flexor carpi ulnaris muscle (FCU), as well as the ulnar half of the flexor digitorum profondus muscle, are not compromised in Guyon's canal neuropathy. The Tinel sign may be positive at the level of the wrist.

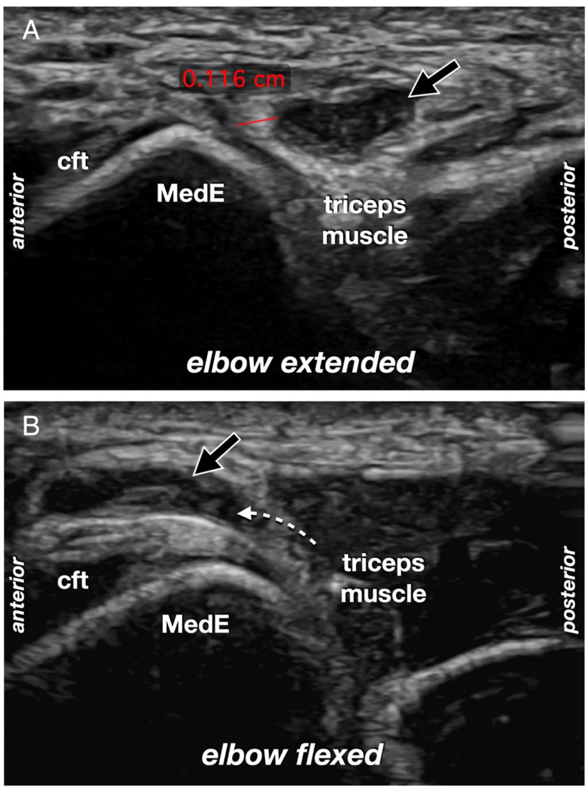
### *US Pathological Findings*

US can reveal alterations of the pathological nerves.[10] In entrapment neuropathies, nerves usually appear enlarged proximal to the site of compression, with the absence of the normal fascicular appearance. Occasionally, the nerves can be enlarged distally.[11] Nevertheless, as specified in the normal findings,[1] the UN exhibits a change in the normal echotexture at the cubital tunnel and may appear mono-, bi-, or tri-fascicular. Cross-sectional area (CSA) can help to define enlarged nerves. For the UN, the most accepted cut-off is 10 mm$^2$ at the level of the elbow. We recommend referring to Part 1 of this review which dedicates a paragraph to the normal and abnormal reported values.[1] Moreover, only a few studies in the literature have attempted to correlate UN CSA with the clinical and/or electrophysiological severity of UN disease at the elbow. Volpe proposed three cut-offs that may define the severity of neuropathy at the elbow: mild ≥10 mm$^2$; moderate ≥15 mm$^2$; and severe ≥20 mm$^2$.[12] Other authors have also found a direct correlation between CSA and severity of disease,[13–15] whereas one group did not.[16]

In repetitive trauma, such as chronic repetitive friction of the UN against the medial epicondyle tip during elbow flexion, in patients with nerve instability/snapping, the UN appears swollen with thickening of the external epineurium (eg, the hyperechoic rim that encircles the nerve) due to fibrotic alterations (Figure 2).[10,17] Moreover, according to Plaikner, epineural thickening is usually not present in idiopathic cubital tunnel syndrome.[17] Epineural thickening is not only found in UN instability but has also been reported, for example, in leprosy, by Visser.[18]

In penetrating injuries, the nerve may be completely transected and US can demonstrate a hypoechoic stump neuroma (Figure 1). In-continuity neuromas, in contrast, are related to partial tears; US can depict a hypoechoic mass along the course of the nerve and may demonstrate scar tissue near it (Figure 3). These injuries may occur at various levels since the UN and its branches are superficial along their course.[1]

**Figure 2.** UN snapping at the elbow. **A** and **B,** Short-axis of the UN (black arrow) at the elbow during different positioning. In (**A**), the patient is observed with the elbow extended. The UN lies in its expected place, posterior to the medial epicondyle (MedE). Note the hyperechoic external epineurium appears more evident (it is measured, 1.1 mm) due to fibrotic changes. In (**B**), the patient flexes his elbow. The UN is now anterior to the medial epicondyle, over the common flexor tendons (cft). The triceps muscle does not luxate. The patient reported intermittent dysesthesia of the two ulnar fingers, which was aggravated during the night and after extensive elbow flexions (eg, muscle training).



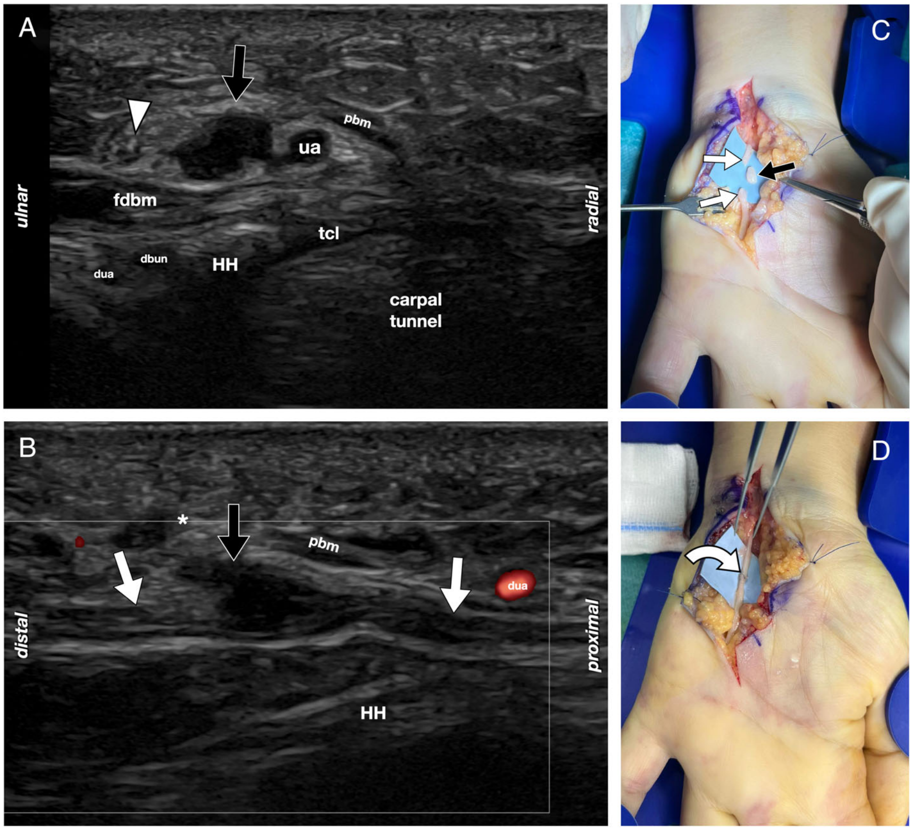

Furthermore, tumors may affect the UN, and the main role of US is to demonstrate the mass continuity with a nerve structure and to guide biopsy if needed (Figure 4).[19] US has also been shown to possibly suggest diagnosis in dysimmune neuropathies, with diffuse or multifocal enlargement that affects the nerve in an irregular pattern (Figure 5).[20,21] It is beyond the scope of this article to provide an in-depth description of these neuropathies.

Starting from proximal to distal, pathology at the upper arm of the UN is uncommon. The passage through the medial intermuscular septum and at the arcade of Struthers are reportedly the first locations of entrapment. As described in the first part of the article, anatomical variants are not uncommon, and in some healthy people, the passage of the nerve through a septum or over a tendinous structure can be visualized without pathology or a clinical meaning.[11] A clear nerve alteration in US related to its course at the upper arm, and corresponding to UN pathology, is rare in our experience (Figures 6 and 7). When such an alteration is depicted, we report the approximate distance to the medial epicondyle and photograph the patient with the exact location of the transducer position to help orthopedic surgeons in eventual surgical planning. In patients with UN entrapment at the elbow, we also report whether the UN has a clear change in its course over a tendinous/ligamentous structure at the upper arm, which may cause a new point of nerve entrapment after surgery, especially in patients with anterior transposition.[22]

A rarely described accessory muscle at the arm is the chondroepitrochlearis, which originates as an accessory slip from the pectoralis major muscle, descends the medial part of the arm, superficial to the median nerve and UN, and inserts at the medial epicondyle (Figure 8); possible compression of the UN has been reported in the literature.[23]

Most frequently, pathologies of the UN occur at the level of the elbow. Compressions are usually reported in the literature at two locations: the retro-

**Figure 3.** Penetrating injury. In-continuity neuroma. Distal Guyon's canal. **A** and **B**, Axial b-mode (**A**) and long-axis Power Doppler (**B**) sonograms of the ulnar region of the distal wrist, at the level of the hook of the hamate (HH), in a patient with a recent (1 month) penetrating injury from broken glass. Patient reported sudden dysesthesia of part of the 4th and 5th fingers. The glass pieces were removed at the time of the injury. In (**A**), a hypoechoic neuroma (black arrow) is depicted along the course of the common digital nerve of the 4th webspace. Note the normal proper digital nerve of the 5th finger (white arrowhead), as well as the DBUN. The ulnar artery (ua), and the deep ulnar artery (dua), which follows the DBUN, were normal. In (**B**), the lesion was confirmed to be a neuroma in-continuity; the nerve appeared normal proximal and distal to it (white arrows). The palmaris brevis muscle (pbm) appears interrupted (asterisk) at the level of the neuroma. **C** and **D**, Intra-operative findings. The neuroma was excised in (**C**), neurorrhaphy (curved white arrow) was performed in (**D**). Courtesy of Piergiuseppe Zampetti MD, Firenze, Italy. TCL indicates the distal part of the transverse carpal ligament.

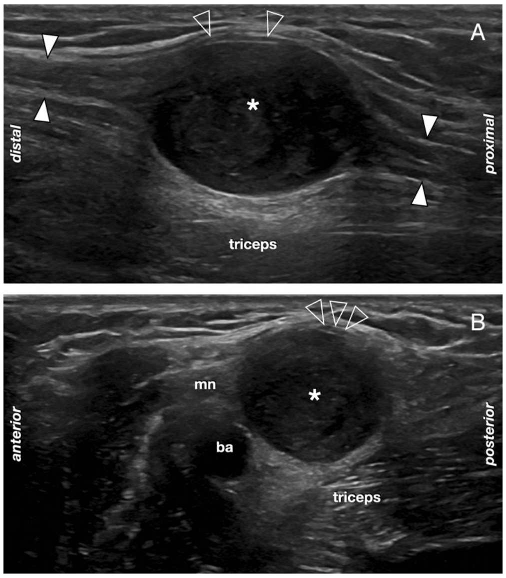



epicondylar area (or condylar groove) and the cubital tunnel at the level of the arcuate ligament (Osborne arcade, humeroulnar aponeurotic arcade).[24] Ultrasound and Magnetic Resonance Neurography have been proposed to locate nerve entrapment at these locations.[25,26]

In detail, according to Omejec and Podnar, US can demonstrate constriction at the level of the humeroulnar arcade, usually 2 or 3 cm distal to the medial epicondyle. They concluded that, in nerves without a clear constriction, it is more difficult to precisely locate the nerve entrapment region, proposing that nerves with maximal CSA distal to the medial epicondyle may be related to entrapment at the humeroulnar arcade, whereas in nerves with maximal CSA at the level of or proximal to the medial epicondyle, the compression is in the retro-epicondylar area.[26]

We also believe that US can depict UN compression at the cubital tunnel, particularly during elbow flexion. It is possible to demonstrate the compression point, with the nerve compressed between the floor of the tunnel (posterior band of the ulnar collateral ligament, pbUCL) and the roof (Osborne retinaculum/arcade). A "notch sign" is usually determined by the roof, associated with maximal nerve swelling, in our experience, more commonly evident proximally (Figure 9). Elbow flexion is therefore always advised

**Figure 4.** Tumor of the UN. **A** and **B**, Long (**A**) and short (**B**) axis sonograms of the UN just below the axilla depict a hypoechoic oval mass (asterisk), with well-defined margins, in-continuity with the normal proximal and distal UN (indicated by the white arrowheads). The mass shows a mild posterior acoustic enhancement. Some of the normal fascicles (open arrowheads) can be seen at the periphery, superficial to the mass. These described US features suggest a schwannoma. Ba, brachial artery; mn, median nerve.




to possibly demonstrate an entrapment. Mostly, it is difficult to precisely determine whether the structure compressing the UN is the Osborne retinaculum or the arcade since the two structures are in continuity; this is the reason most decompressive surgery releases both areas.[1]

At the retro-epicondylar area, a shallow groove and cubitus valgus are reported to possibly cause UN neuropathy.[24] Moreover, instability of the nerve may predispose the UN to pathology. The nerve can be seen subluxating or luxating over the tip of the medial epicondyle during elbow flexion (Figure 2). Instability is believed to be secondary to the absence or hypoplasia of the Osborne retinaculum or its laxity.[27,28] This condition is mainly paraphysiological and can be seen in around 20% of asymptomatic persons,[29] but it seems that it may be linked to UN neuropathy. The usually reported mechanism is thought to be related to the irritation of the nerve over the bone, with chronic repetitive friction at the retro-epicondylar groove,[10,30] but we also believe that the entrapment/dynamic compression exerted on the nerve by the Osborne arcade (since the retinaculum in these patients is absent/hypoplastic/lax) during elbow flexion has a role (Figure 10).[28] A subtype of UN

**Figure 5.** Dysimmune neuropathy of the UN. **A**, Longitudinal sonogram of the UN at the distal forearm depicts atypical and abrupt enlargement of fascicles of the UN (black arrowheads) at a non-compressive site. The nerve is normal proximally (indicated by the white arrowheads). **B** and **C**, Axial sonograms obtained at the distal forearm a bit distal (**B**) and proximal (**C**). In (**B**), some of the fascicles are swollen (black arrowheads), whereas others are normal (white arrowhead). In (**C**), the UN appears regular with a normal fascicular pattern. Fcu, flexor carpi ulnaris; fdp, flexor digitorum profundus; fds, flexor digitorum superficialis; ua, ulnar artery.

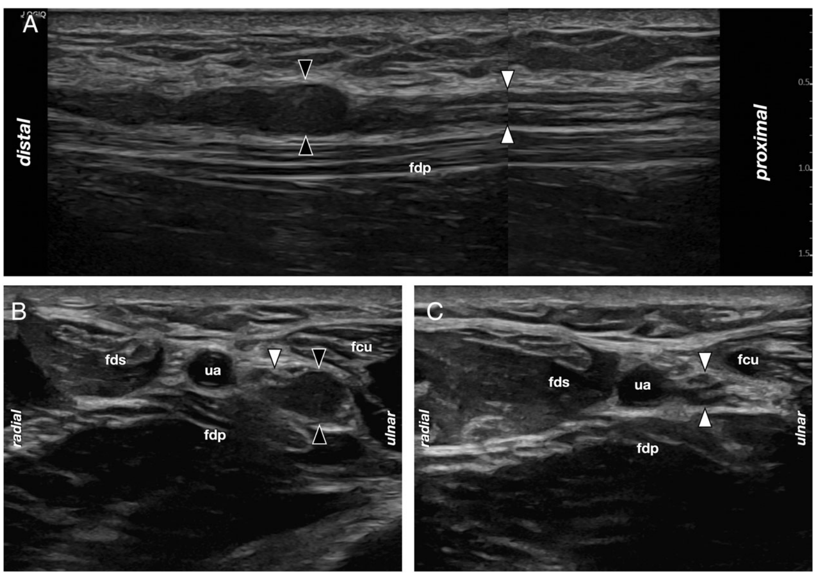
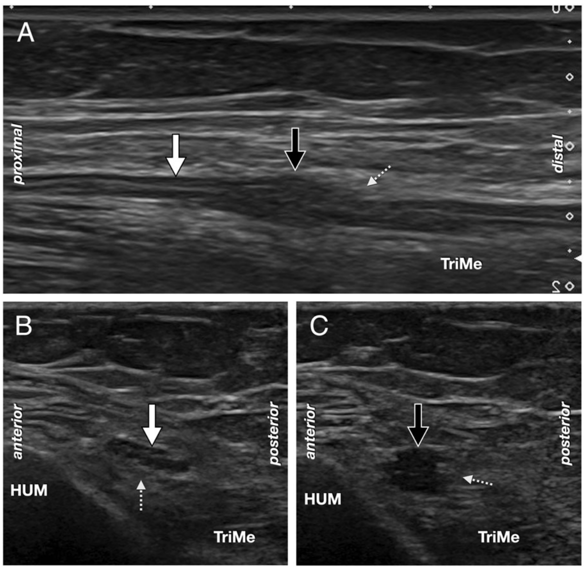


**Figure 6.** UN entrapment when crossing a tendinous structure interpreted as the internal brachial ligament (IBL) at the middle-third of the upper arm. The IBL is a non-constant tendinous/ligamentous cord that may cross the UN; we suggest reading Part 1 of this article for more anatomical details. **A**, Long-axis of the UN at the middle-third of the upper arm in an elderly patient who developed UN palsy after long hospitalization for Covid. Note the UN (white arrow) is thickened (black arrow) while passing near a tendinous structure (dashed arrow). **B** and **C**, Axial sonograms proximal (**B**) and distal (**C**) demonstrate the passage of the tendinous structure deep to the UN (**B**) and then posteriorly (**C**). The nerve is enlarged with loss of a normal fascicular pattern. No other sites of nerve entrapment were demonstrated along the course of the UN. Cervical MRI did not show cervical root compressions. A possible diagnosis of entrapment at the IBL related to concomitant external compression by a bed rail was hypothesized. HUM indicates the humerus; TriMe, medial head of the triceps muscle.




instability is the so-called snapping triceps syndrome,[29] in which the triceps muscle snaps anterior to the medial epicondyle after the UN, during elbow flexion (Figure 10). To diagnose a snapping triceps, symptoms and/or snapping should be present, since movement of the muscle over the bone is not necessarily pathologic. Moreover, snapping of the medial head of the triceps can cause mechanical symptoms and/or pain without nerve-related symptoms. Furthermore, even if not common, the triceps may snap without UN luxation.[31]

Laxity of the retinaculum may also be secondary to elbow fracture and/or surgery.

A hypertrophic or accessory medial head of the triceps can compress the UN due to mass effect at the retro-epicondylar groove. It may be difficult to clearly define when hypertrophy is present, but Schertz proposed hypertrophy should be defined if the triceps muscle occupies more than 50% of the surface of the ulnar groove with the elbow 90° flexed, and exerts a mass effect on the UN during full elbow flexion.[2] However, this definition has not been validated yet, and it is important to remember that the triceps muscle normally enters the ulnar groove upon elbow flexion in many people. Triceps hypertrophy may also be associated with the previously described snapping triceps syndrome,[31] but this is not the only mechanism that leads to UN neuropathy. In our experience, during elbow flexion, US can demonstrate how a hypertrophic muscle can directly compress the UN to the bone, especially when it does not luxate (Figure 11), possibly causing chronic and repetitive compression neuropathy.

Osteoarthritis of the elbow can lead to synovitis and osteophyte formation at the level of the ulnar groove which may predispose to UN neuropathy (Figure 12), or, more rarely, osteophytes or loose bodies may directly compress the nerve (Figure 13).[32] Other conditions that determine elbow joint damage, such as rheumatoid arthritis and chondrocalcinosis, may be related to UN pathology, as well as ganglion cysts arising from the ulno-humeral joint.[33]

In elbow trauma, fractures can be associated with UN neuropathy,[34] and symptoms may be delayed, for example, related to osseous reorganization or due to inflammation of the cubital tunnel.[35]

Injuries involving the pbUCL, forming the floor of the cubital tunnel, particularly avulsion fractures, may give rise to UN pathology (Figure 14).

In addition, US can be useful to demonstrate iatrogenic complications such as impingement with screws used to treat fractures (Figure 15).[36] Ulnar neuropathy may also follow surgical repair of ulnar collateral ligament injury, with or without nerve transposition.[37] UN neuropathy may be related to the proximity of the nerve to the ligament. US has been shown useful in demonstrating constriction of the UN by suture material,[38] or depicting impingement of the nerve with suture anchors.[39] Some authors propose UN transposition as a routine part of ulnar collateral ligament repair, whereas others include UN transposition only in cases of preoperative UN symptoms.[40] The complications of UN transpositions, which are described later, may arise (Figure 16).

**Figure 7.** Tendinous slip (which we believe is usually reported as the distal medial intermuscular septum) compressing the nerve at the distal upper arm. **A**–**C**, Transverse sonograms of the UN from proximal (**A**) to distal (**C**). In (**A**), the UN (black arrowhead) is a bit thickened, anterior to a tendinous slip (curved arrow). In (**B**), the nerve passes over the slip, and is finally posterior to it in (**C**). **D**, the long-axis of the nerve is depicted, confirming a possible point of entrapment, which is absent at the contralateral healthy side (**E**), where the normal UN is indicated by the white arrows. Patient presented with UN palsy that arose 6 months before; at US, another possible site of compression was found at the distal Guyon's canal (not shown), which could be related to the use of a tight wristband for tendinopathy, as the patient reported. It was hypothesized that the two regions of nerve compression led to the clinical scenario. HUM indicates the humerus; TriMe, medial head of the triceps muscle.

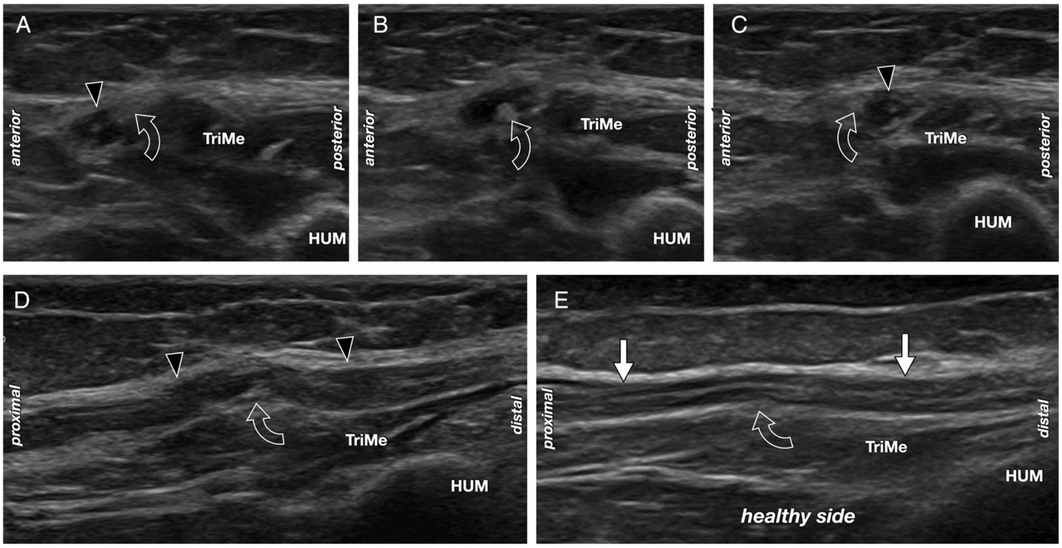



**Figure 8.** Chondroepitrochlearis muscle. Variant. **A**–**D**, Axial sonograms from proximal (**A**) to distal (**D**) starting from the pectoral region (**A**), to the proximal (**B**), middle (**C**), and distal (**D**) third of the upper arm. In (**A**), note a small muscular extension (open arrowhead) on the most lateral side of an otherwise normal pectoralis major. In (**B**), at the proximal third of the arm, the accessory muscle passes over the fascia, over the median (mn) and ulnar nerve (un), and over the brachial artery (ba). In (**C**), at the middle-third of the arm, the aberrant muscle lies in the posterior compartment, over the UN and the triceps muscle. In (**D**), near the elbow, the chondroepitrochlearis inserts at the medial epicondyle (MED EP). **E**, Clinical picture of the patient showing the variant muscle. The patient was asymptomatic. Corac, coracobrachialis muscle; HUM, humerus; rn, radial nerve.

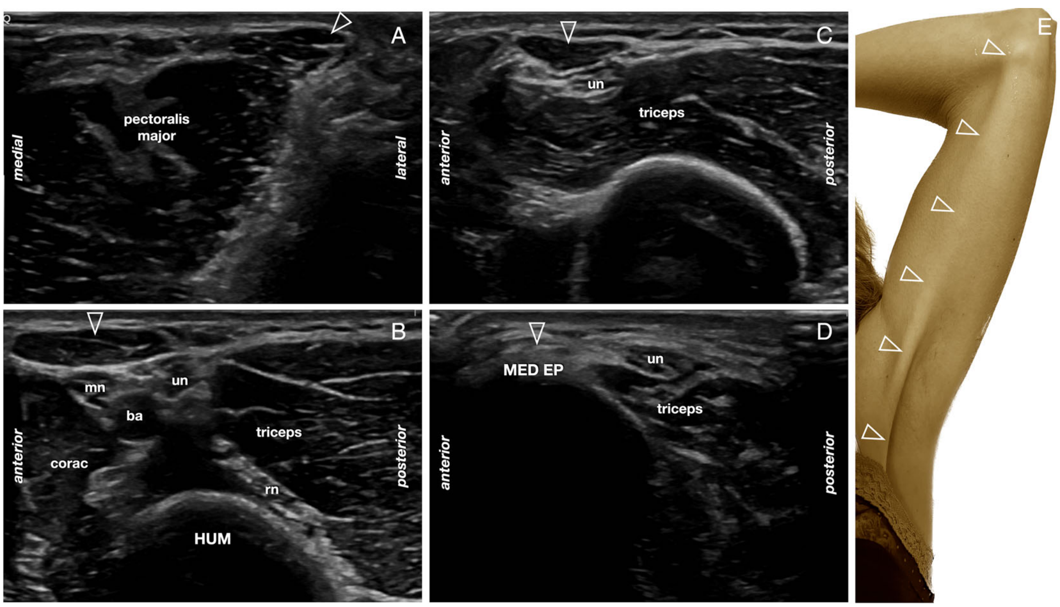


**Figure 9.** Cubital tunnel syndrome. Effect of different positioning. **A** and **B**, Longitudinal sonograms of the passage of the UN at the elbow in a patient with clinical findings of UN entrapment and electrodiagnostic tests suggestive of cubital tunnel syndrome. In (**A**), the elbow is extended, whereas, in (**B**), it is flexed. Note the clear "notch sign" depicted in (**B**) by the Osborne retinaculum/arcade (curved black arrow) with a thickened UN proximally (black arrow) and more preserved distally (open arrow). There is fluid distending the humero-ulnar joint (asterisk), deep to the pbUCL. In (**C**), intraoperative findings match closely the US picture with a compressed UN. Patient underwent anterior nerve transposition. In (**D**), split screen axial sonogram comparison at the medial epicondyle (Med Ep). The UN is clearly enlarged on the left, with a CSA of 22 mm$^2$; note the normal nerve on the right, at the healthy contralateral side with an area of 9 mm$^2$. HUM, humerus.

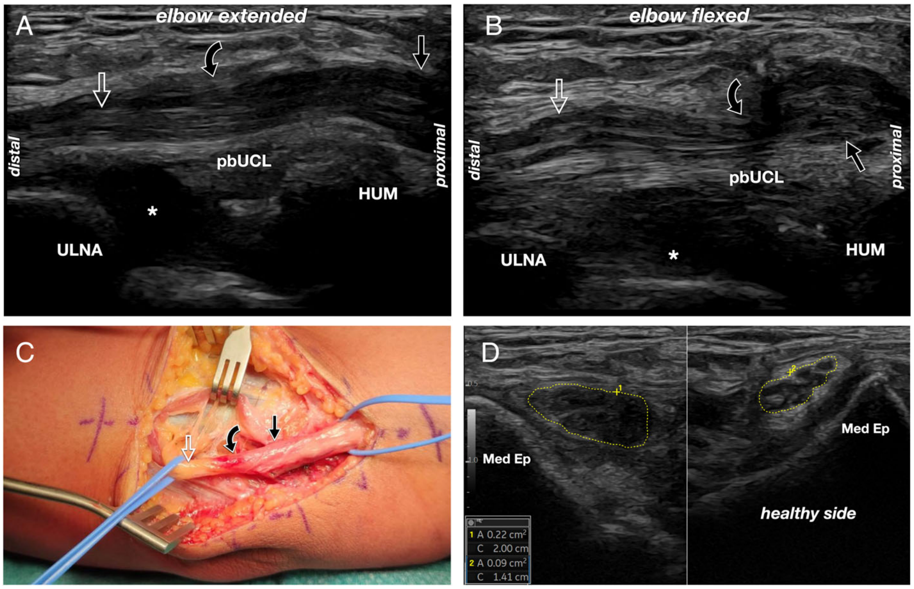



**Figure 10.** Snapping triceps at the elbow. **A** and **B**, Short-axis of the UN (black arrow) at the elbow during different positioning. In (**A**), the UN is posterior to the medial epicondyle (MedE). In (**B**), during flexion, not only is the UN displaced anteriorly, but also a part of the triceps muscle. Clinically, it can be sometimes perceived by the patient as two palpable snaps. **C**, With the patient still flexing the elbow, the probe is rotated over the long axis of the common flexor tendon (cft). The UN can be clearly depicted superficial to it. In (**D**), the probe is shifted a bit posteriorly. Note the Osborne arcade (curved arrow), which compresses the nerve a bit, which clearly changes it course. A question may arise: which is the main mechanism for neuropathy? Nerve friction over the medial epicondyle or nerve entrapment during flexion at the Osborne arcade?

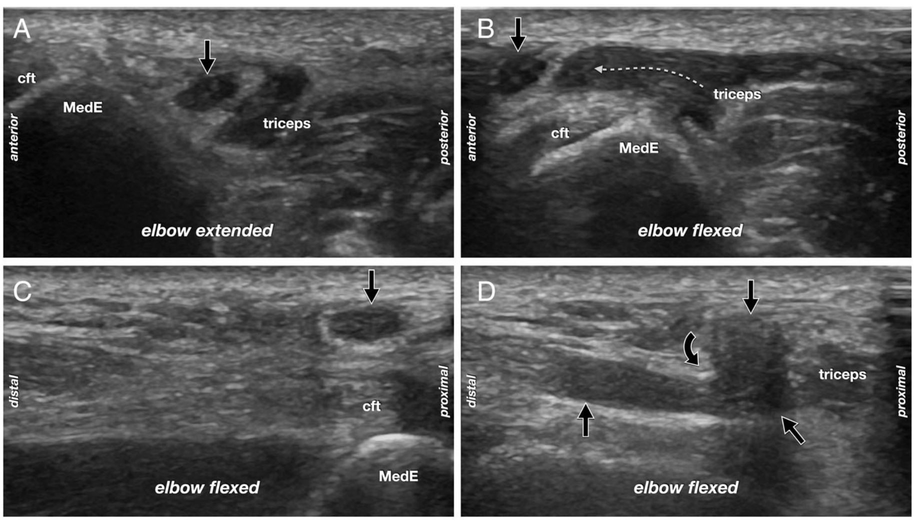
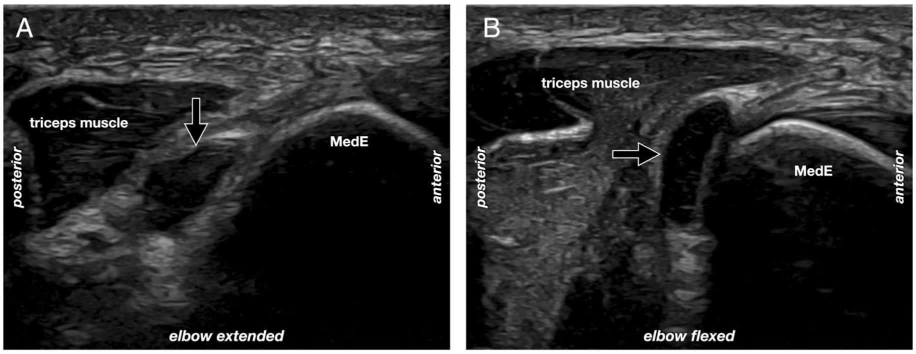


**Figure 11.** UN compression in triceps hypertrophy. **A** and **B**, Short-axis of the UN (black arrow) at the elbow during different positioning in a young sports enthusiast who presented with occasional dysesthesia of the two ulnar fingers, mainly when practicing sports. In (**A**), the elbow is extended, the UN is indicated by the black arrow. In (**B**), when the elbow is flexed, a compression of the nerve exerted by a hypertrophied triceps against the bone (MedE) is evident. Interestingly, despite quite a large nerve (maximal CSA was just distal to this point, around 20 mm$^2$, only a bit more than the contralateral side), there were no alterations of the muscles supplied by the UN.




The anconeus epitrochlearis is an accessory muscle with variable reported prevalence, ranging from 0 to 34% of individuals, which may replace the Osborne retinaculum.[41] Although it is reported to be a possible cause of compression of the UN at the elbow (Figure 17), some authors believe it may have a protective role against cubital tunnel syndrome.[42] The anconeus epitrochlearis can be differentiated

**Figure 12.** UN neuropathy in elbow osteoarthritis. **A**, Short-axis sonogram of the UN (black arrowhead) as it approaches the cubital tunnel. Note an osteophyte (black curved arrow) and joint synovitis involving the floor of the tunnel (asterisk). **B**, Proximally, the nerve (black arrow) is severely enlarged, with a CSA of 38 mm$^2$. **C**, Long-axis of the UN. The nerve is clearly enlarged proximally. Patient presented with ulnar hand paresthesia and atrophy of the intrinsic muscle of the hand supplied by the UN. HUM indicates the humerus; MedE, medial epicondyle.

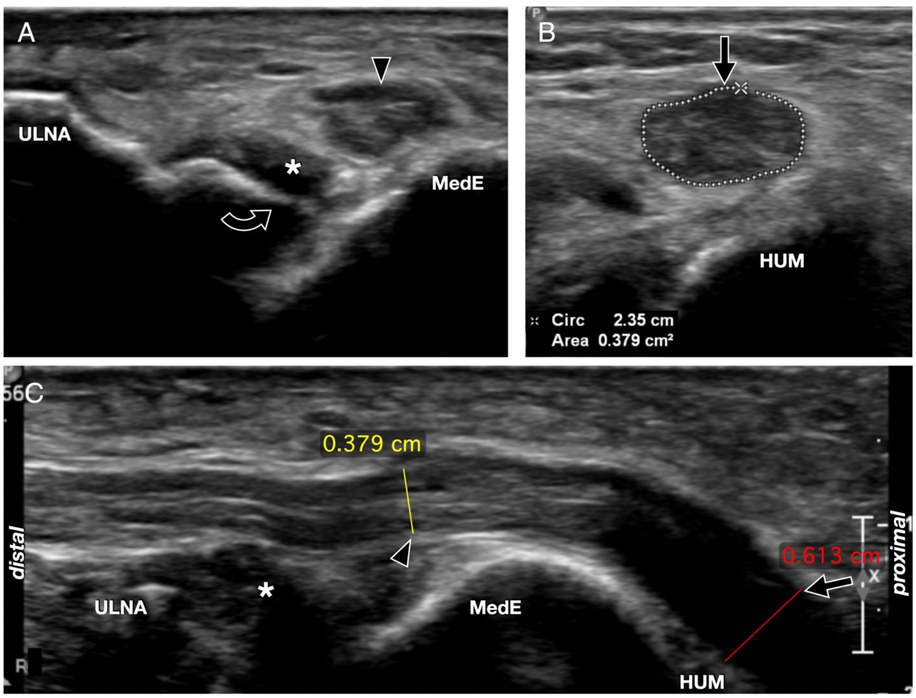


**Figure 13.** UN neuropathy in an older patient with osteoarthritis. Calcific loose body directly compress the UN. **A**, Long-axis of the UN at the elbow in a patient with long-standing ulnar neuropathy. The UN is markedly flattened (black arrowhead) when passing over a calcific structure (curved arrowhead), enlarged proximally (black arrow). The calcific structure was not in continuity with the bone, and therefore, an osteophyte was excluded and it was interpreted as a loose body in osteoarthritis. Possible differential diagnosis includes dystrophic calcification. **B** and **C**, Axial sonograms at the level of the compression (**B**) and proximally (**C**) confirm the findings. MedE, medial epicondyle.

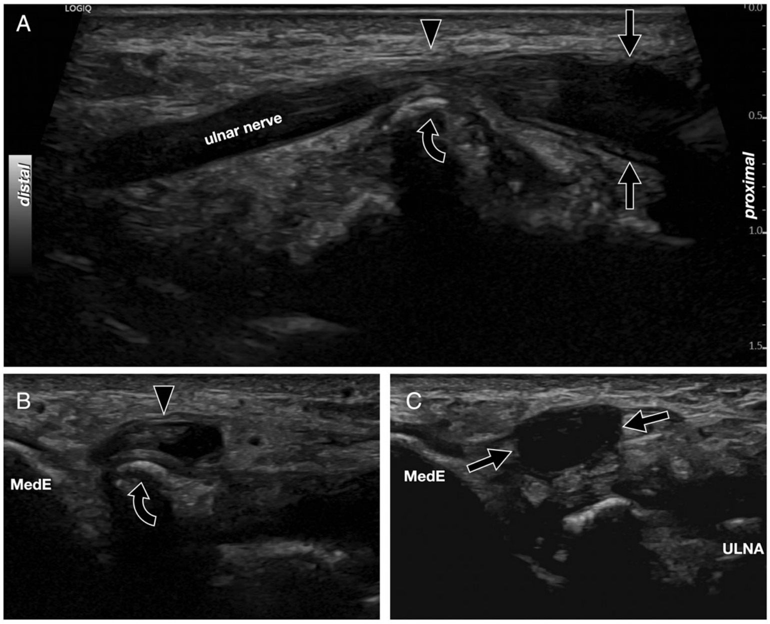



**Figure 14.** UN irritation in pbUCL avulsion. **A** and **B**, Axial b-mode (**A**) and microvascular imaging (**B**) of the cubital tunnel in a patient who developed paresthesia of the 4th and 5th finger 1 month after starting rehabilitation for a mild radial head fracture. US demonstrated a small avulsion of a bony fragment (black arrowhead) from the olecranon (Ol) attachment of the pbUCL (asterisk). The UN (black arrow) had a normal CSA (7 mm$^2$), but there was an evident surrounding hyperemia. The hyperechoic epineurium is more evident, possibly suggesting nerve friction-irritation with contiguous tissues of the cubital tunnel. Note the interrupted Osborne retinaculum (curved black arrow) at its midportion, thickened at its attachment. **C**, Axial CT also demonstrates the small bony avulsion, which was missed on x-ray. **D**, Axial STIR MRI showed diffuse edema (hyperintensities) surrounding the UN. Patient's symptoms improved by reducing physiotherapy and repetitive activities of flexion/extension of the elbow. "a" indicates the posterior ulnar recurrent artery; MedE, medial epicondyle.

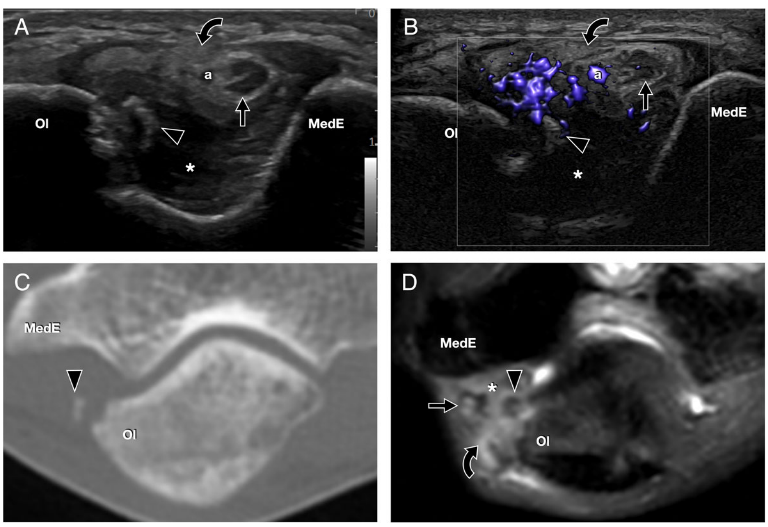
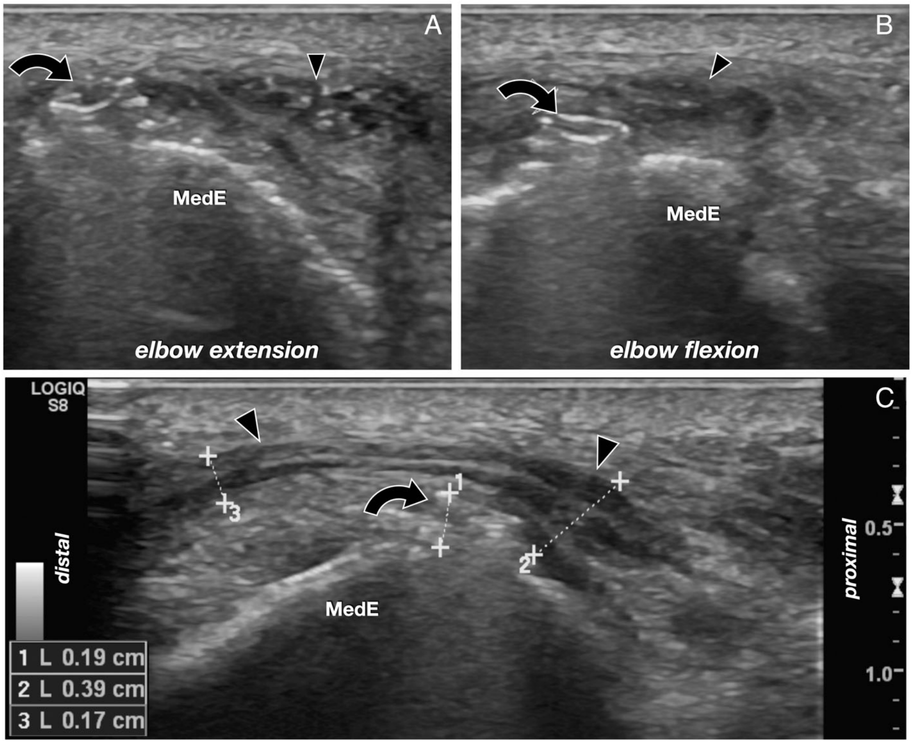


**Figure 15.** UN neuropathy due to irritation from a surgical screw. Patient presented with dysesthesias of the two ulnar fingers without muscle impairment after a surgically fixed supracondylar fracture. **A** and **B**, Axial sonograms obtained at the level of the medial epicondyle (MedE). During extension (**A**), the ulnar nerve (black arrowhead) had no direct contact to the screw (curved arrow). In a flexed elbow position (**B**) the nerve was directly irritated by the screw. **C**, Longitudinal sonogram of the UN showing the contact of the nerve with the screw (curved arrow). The nerve is thickened (caliper 2) just proximal to the screw (caliper 1), whereas it appears normal distally (caliper 3).




from the triceps with proximal axial sonograms, which demonstrate it as a separate entity from the latter muscle. Moreover, the accessory muscle proceeds over the cubital tunnel in contrast to the triceps.[43]

Surgical options for UN entrapment at the elbow include in situ decompression, medial epicondylectomy, and anterior transposition (Figure 18). The latter may be divided into subcutaneous, in which the nerve can be secured with a fascial or muscular flap from the flexor-pronator muscles, intramuscular, and submuscular.[44,45] CSA of the UN has been demonstrated to be enlarged in patients with surgical failure. In fact, in a study of 68 patients with no clinical improvement after surgery, the mean CSA of the UN was 17 $mm^2$, whereas the mean CSA in 48 non-operated patients with cubital tunnel syndrome was 13 $mm^2$. However, the authors collected data about the pre-operative CSA in only six patients, in which the nerve was smaller before surgery. Moreover, the main limitation of this study seems to be that the authors did not compare the patients with no improvement to the patients who underwent surgery and had a good outcome.[46] Another recent study, performed in 23 subjects who underwent subcutaneous transposition for UN neuropathy, demonstrated that, post-operatively at MRI, the UN is generally larger and more T2-hyperintense when compared with pre-operative MRI, but these features are not directly related to surgical failure.[47] In our opinion, the usual cut-off of 10 $mm^2$ for UN neuropathy at the elbow cannot be used after surgery, particularly if it cannot be compared with pre-surgery values. In patients who improve after surgery, the CSA may decrease (Figure 18), but we have not found in the literature a standardized timing with which to possibly demonstrate CSA reduction. However, persistent CSA enlargement, especially in the first months after surgery, may be found in patients who are clinically

**Figure 16.** Nerve compression after ulnar collateral ligament repair and UN submuscular transposition. **A**–**C**, Axial sonograms from proximal (**A**) to distal (**C**) of the UN at the elbow in a patient with ulnar collateral ligament (ucl) repair and nerve anterior transposition. The UN is normal proximally (in **A**, white arrow), thickened (in **B**, black arrow) just before the medial epicondyle (MedE), and compressed in **C**, possibly between tendinous bands (curved white arrows). The Tinel sign was positive when pressing in this latter area (**C**). **D**, Longitudinal sonogram confirms the normal nerve proximally (measured in green), the entrapped nerve at the medial epicondyle (yellow), and the thickened UN just proximally (measured in red). Note irregularities of the medial epicondyle and the ulnar collateral ligament related to previous injury and surgery. HUM, humerus; TriMH, medial head of the triceps.

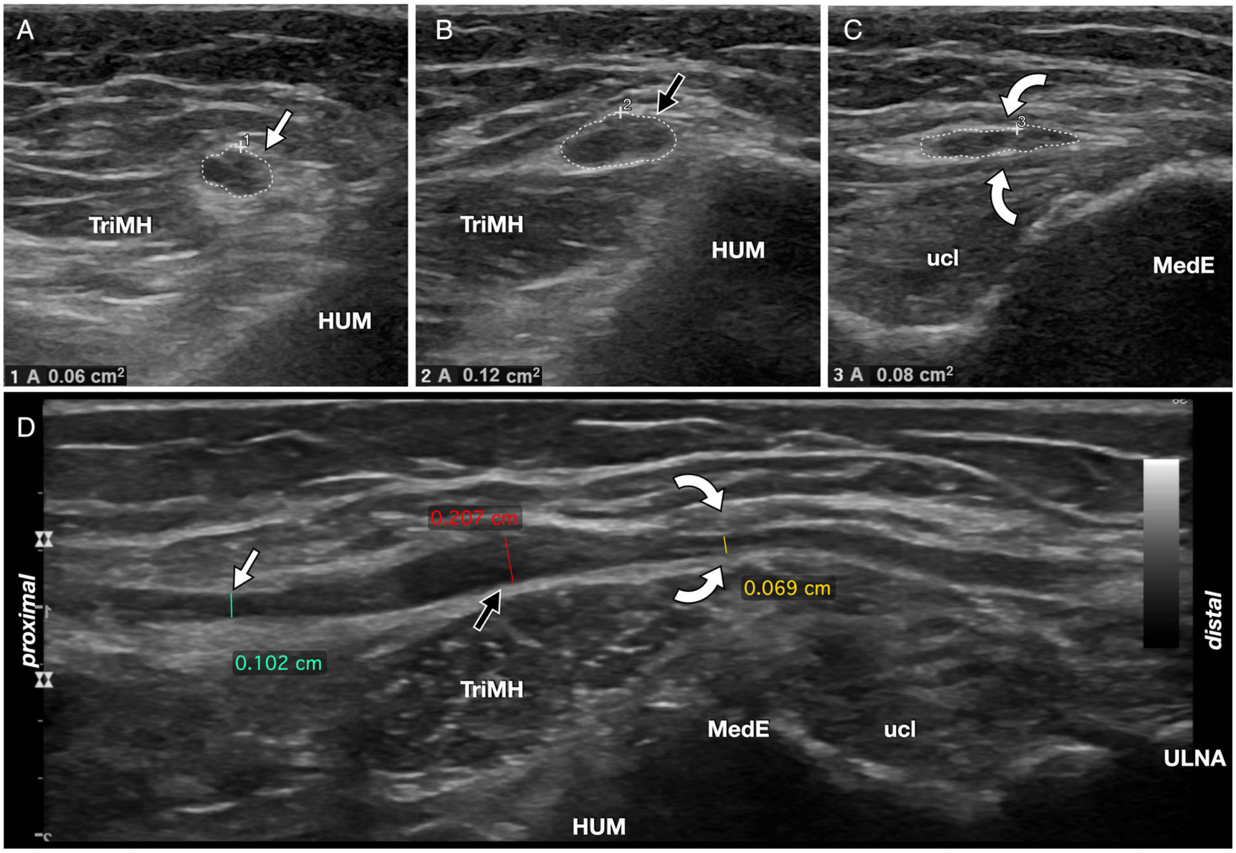



**Figure 17.** Anconeus epitrochlearis and UN neuropathy. **A** and **B**, Transverse (**A**) and longitudinal (**B**) sonograms of the UN (black arrowhead) at the left elbow in a patient with atrophy of the intrinsic muscles of the hand supplied by the UN. The CSA of the nerve is increased (around 17 mm$^2$). The anconeus epitrochlearis (ae) was thought to have a possible role in nerve compression. However, the variant was present bilaterally, and the UN had a CSA of 13 mm$^2$ in the right side, without any clinical sign of palsy. In our opinion, it can be difficult to clearly demonstrate at imaging the role of this variant in compressive neuropathy. MedE, medial epicondyle; Ol, olecranon.

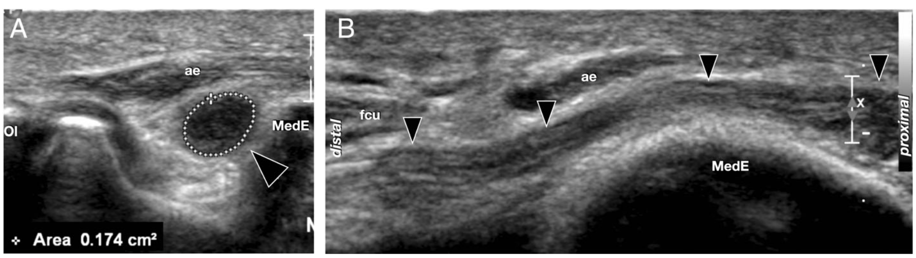
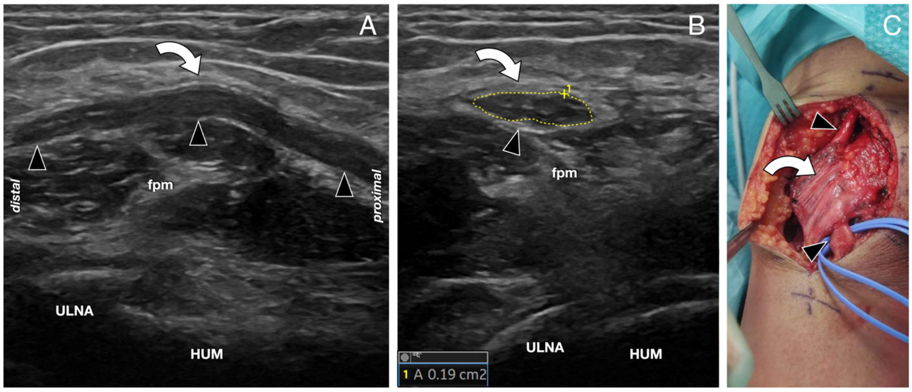
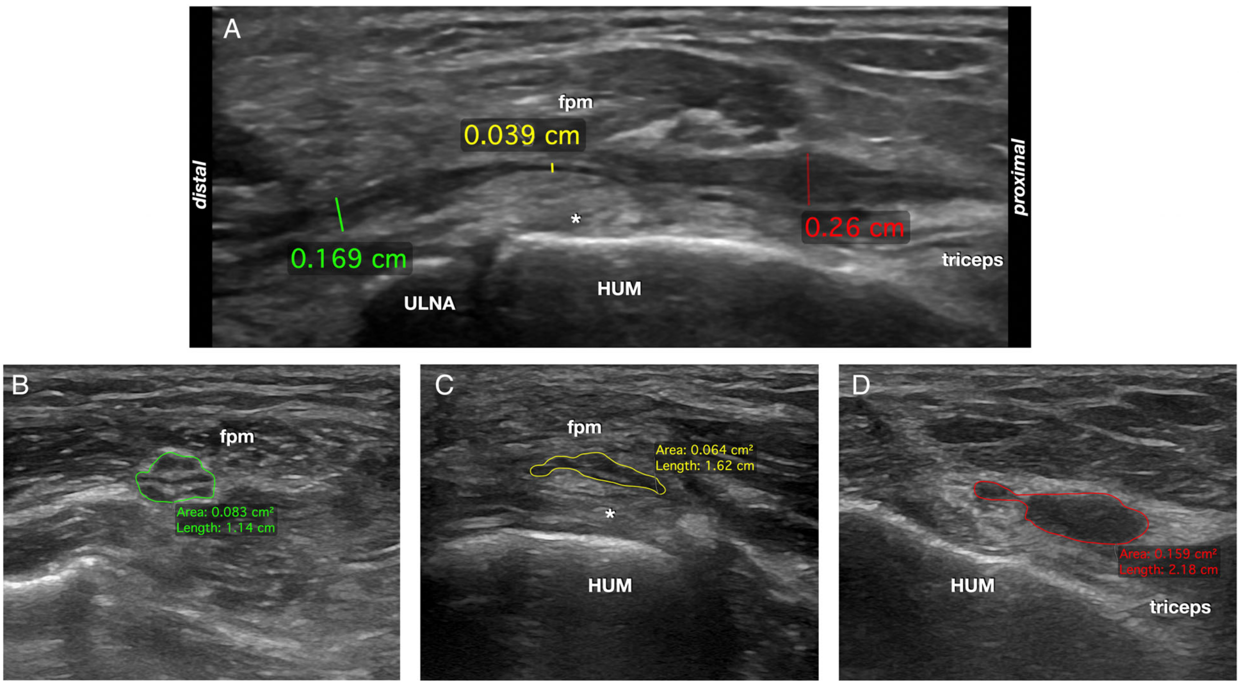


**Figure 18.** Anterior transposition of the UN with clinically demonstrated improvement. **A** and **B**, Long- and short-axis sonograms of the UN (black arrowhead) obtained 1 year after anterior transposition in a patient (same as Figure 9) with clinical improvement after surgery. The nerve was covered by a fascial sling (curved white arrow, also well demonstrated during surgery, in (**C**)), passing over the flexor-pronator group of muscles (fpm). Note that the CSA is still enlarged (19 mm$^2$) but reduced (it was 22 mm$^2$). Patient gained hand dexterity, with clinically appreciable improvement in muscle trophism (also at US) after surgery. HUM, humerus.




improving. Moreover, even if increased CSA (with regard to pre-surgery values) may raise concern and should be reported, it also does not necessarily reflect surgical failure. Therefore, we suggest evaluating CSA measures with caution in the post-operative phase since imaging findings should not be interpreted

**Figure 19.** Nerve compression after submuscular transposition. **A**, Long-axis of the UN at the elbow in a patient with anterior (submuscular) transposition and clinical worsening after surgery, with progressive pain especially in the ulnar two fingers. The UN is thickened proximally (in red), flattened (in yellow) at the level of the joint between the flexor-pronator group of muscles (fpm), and the anterior part of the ulnar collateral ligament (asterisk); normal distally (in green). **B**–**D**, Axial sonograms from distal (**B**) to proximal (**D**) confirm a normal nerve in (**B**), a flattened nerve in (**C**), and a thickened nerve in (**D**). HUM, humerus.



without clinical data. Nevertheless, US can help in cases of surgical failure and/or complications. The examination should be focused on depicting alterations of the nerve course and/or demonstrating a focal compression (Figure 19), nerve kinking (Figure 20), or excessive scarring/perineural fibrosis. As demonstrated by Sivakumaran, some grade of scarring near the nerve may be present also in patients without recurrent symptoms.[47] In our experience relevant perineural fibrosis appears as soft tissue changes that encompass the nerve, usually with poor demarcation of the nerve from the area of fibrosis and associated local nerve alterations. Perineural fibrosis may be seen after surgery, not only following UN transposition (Figure 21).[45,48]

According to Morag et al, a decreased gliding during elbow flexion/extension may also indicate impingement of the UN at the medial intermuscular septum.[22]

A blinded injection may damage the nerve or, when cortisone is used, cause atrophy of the subcutaneous tissue and skin depigmentation (Figure 22); therefore US is advised as a guide when performing injections.[49]

A possible confounder for cubital tunnel syndrome is the medial antebrachial cutaneous nerve, which supplies the skin of the ulnar aspect of the forearm. It follows the basilic vein at the arm, to pass the fascia and become subcutaneous in the distal arm. It usually divides into an anterior branch close to the vein and a posterior branch near the medial epicondyle. High-resolution US can demonstrate this small nerve. The nerve may snap like the UN at the elbow and it is at risk of iatrogenic injury during cubital tunnel surgery.[7,50]

Leprosy, an infection related to mycobacterium leprae, commonly affects the UN at the elbow, which usually appears hypoechoic and thickened. In addition, US can also demonstrate abscess.[36]

Just distal to the cubital tunnel, the passage at the flexor pronator aponeurosis where the nerve enters the forearm is another reported area of compression.[51–53] In our experience, this entrapment is uncommon; the UN has a normal appearance at the cubital tunnel whereas it is compressed in proximity to the coronoid tubercle (Figure 23).

At the forearm, UN pathology is rare. Fracture of the distal radius, especially in high-energy trauma possibly with other associated fractures, may result in UN palsy (Figure 24).[54]

**Figure 20.** Nerve entrapment after anterior subcutaneous transposition. Longitudinal sonogram at the level of the elbow in a patient with an anteriorly subcutaneous transposed UN (black arrows) and no clinical improvement after surgery. During elbow flexion, the nerve shows a kinking (curved arrowheads). It was hypothesized that this dynamic entrapment led to surgical failure.

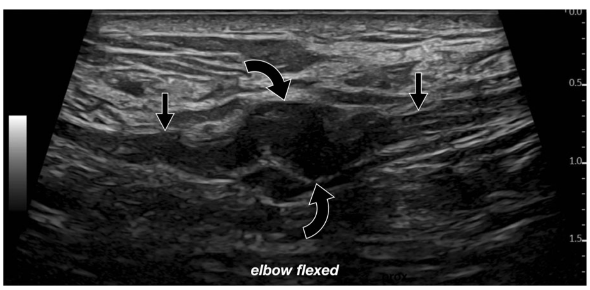



**Figure 21.** Perineural fibrosis encompassing the UN in a patient with a fracture of the proximal ulna (Monteggia fracture), who underwent surgery. **A** and **B**, Axial sonograms from proximal (**A**) to distal (**B**) of the UN at the level of the proximal forearm. In (**A**), there is an inhomogeneous scar (asterisk) superficial to the UN (black arrowheads). Note that a clear demarcation between the nerve and the scar tissue cannot be depicted. In (**B**), just distally, the normal fascicular structure of the UN (white arrowheads) can be clearly depicted. **C**, Corresponding long-axis sonogram of the UN confirms the perineural inhomogeneous tissue (asterisk) surrounding the nerve (black arrowhead), which appears normal proximally and distally (white arrowheads). Findings were interpreted as excessive perineural fibrosis entrapping the UN. Fcu indicates the flexor carpi ulnaris muscle.

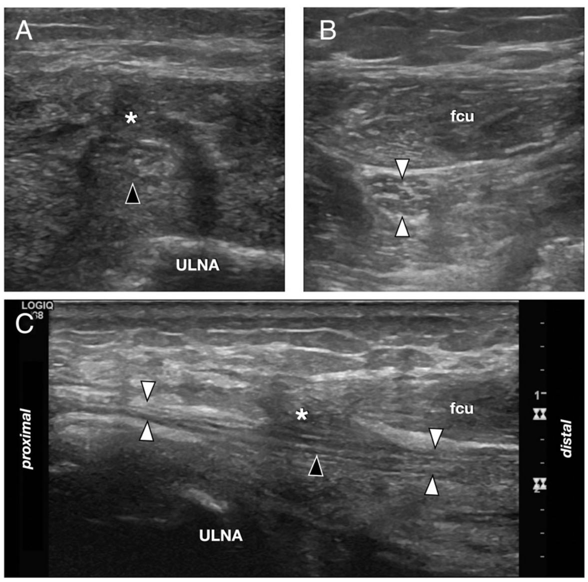
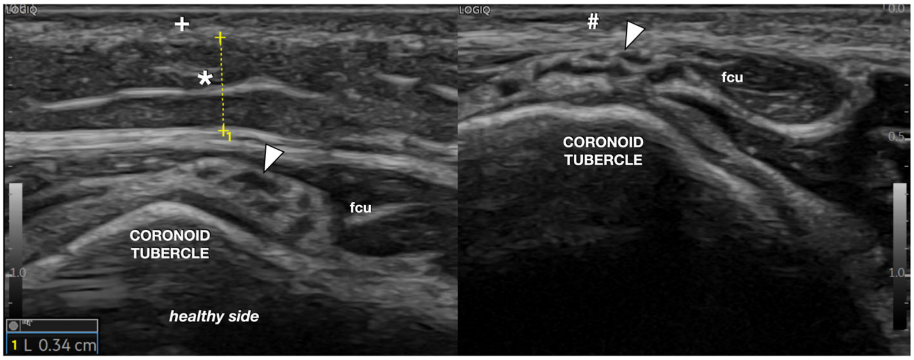


**Figure 22.** Skin atrophy after blinded cortisone injection. Comparative 24 MHz axial sonograms just below the elbow joint, at the level of the coronoid tubercle of the ulna. On the left (the healthy side): it is possible to clearly define the dermis (+), the subcutaneous fat (*, 3.4 mm), and the UN with its normal fascicular pattern (white arrowhead), near the flexor carpi ulnaris (fcu). On the right, note the atrophy and alteration of the subcutaneous fat and the dermis (both indicated by #) in a patient who underwent blinded cortisone injection for suspected UN entrapment. Care was taken to apply the same transducer pressure on both sides to avoid false images related to excessive compression of the subcutaneous tissues.




The DCBUN may be damaged due to trauma or iatrogenic causes related to wrist surgery, both conventional and arthroscopic.[9,55]

The UN and its division at the Guyon canal's may be involved, leading to a different clinical pattern related to the zone of pathology, as described in the clinical part at the beginning of the review. It should also be remembered that DBUN distal divisions may be damaged selectively, giving rise to partial muscle involvement.[56]

**Figure 23.** Entrapment at the flexor-pronator aponeurosis. **A**–**C**, Axial sonograms from proximal (**A**) to distal (**C**) at the level of elbow/proximal forearm. In (**A**), the UN (open arrow) is flattened at the level of the coronoid tubercle (TUB) of the ulna, with a hyperechoic image encircling the nerve, interpreted as the flexor-pronator aponeurosis. **B**, The nerve fascicles (black arrow) are enlarged. **C**, A bit distally, the nerve (white arrow) appears normal. **D**, Long-axis of the UN. The focal enlargement of the nerve is confirmed. Fcu1 and Fcu2, the two heads of the flexor carpi ulnaris muscle; fdp, flexor digitorum profondus; fds, flexor digitorum superficialis.

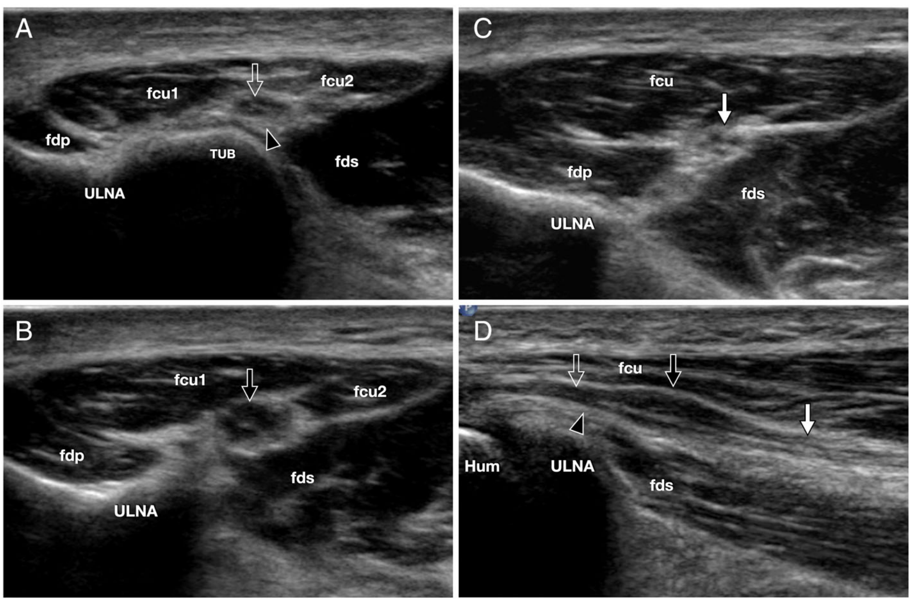


**Figure 24.** Nerve laceration. **A**–**D**, Longitudinal (**A**) and axial from distal (**B**) to proximal (**D**) sonograms of the UN in a patient with UN palsy after a high-impact trauma with open wrist fracture dislocation and distal radioulnar joint dissociation. In **A**, there is an amputation neuroma (black arrowheads) along the course of the UN (white arrowheads). The neuroma is evident in the axial image in (**D**). The distal stump is indicated by the black arrow, and can also be seen in the axial image in (**B**). Between the stumps, hyperechoic scar tissue (asterisk) is depicted. **C** is the corresponding axial image at this level. **E**, Radiography at the time of the fracture. a indicates the ulnar artery; fcu, flexor carpi ulnaris muscle; fdp, flexor digitorum profundus.

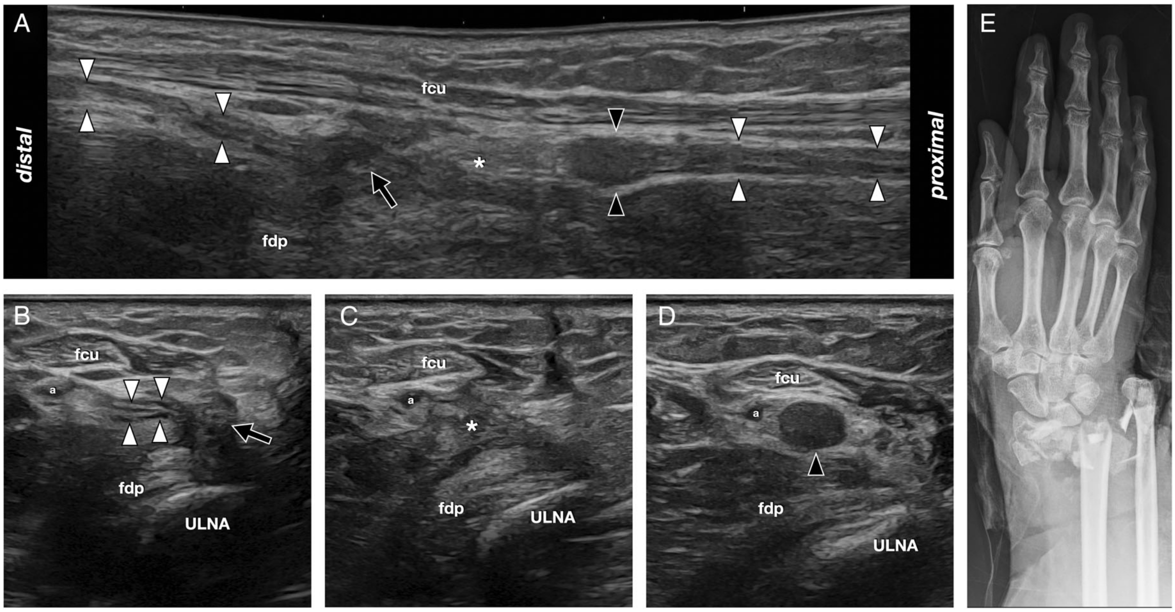



**Figure 25.** Small ganglion cyst compressing the DBUN. **A**–**C**, Axial Power Doppler sonograms from proximal to distal at the level of the Guyon's canal in a patient with a loss of hand dexterity, without sensitive alterations. Electrodiagnostic test demonstrated motor involvement of the intrinsic muscles of the hand supplied by the UN. Exquisite details are obtained with a 24 MHz hockey stick (ie, small footprint) transducer. A ganglion cyst (g) can be seen near the DBUN (black arrowhead). The motor branch is compressed, at first (**A**,**B**) between the ganglion and the piso-hamate ligament (ph lig) and mostly (**C**) between the hook of the hamate (HH), the ganglion, and the fibrous arcade of the hypothenar muscles (arc). The SBUN (white arrowheads) is normal, crossed in (**B**) by the deep branch of the ulnar artery (dua) detaching from the ulnar artery (ua). **D**, Long-axis of the DBUN. The nerve is enlarged near the arcade. Fdm/odm, flexor digiti minimi and opponens digiti minimi muscles; pbm, palmaris brevis muscle; pm lig, pisometacarpal ligament.

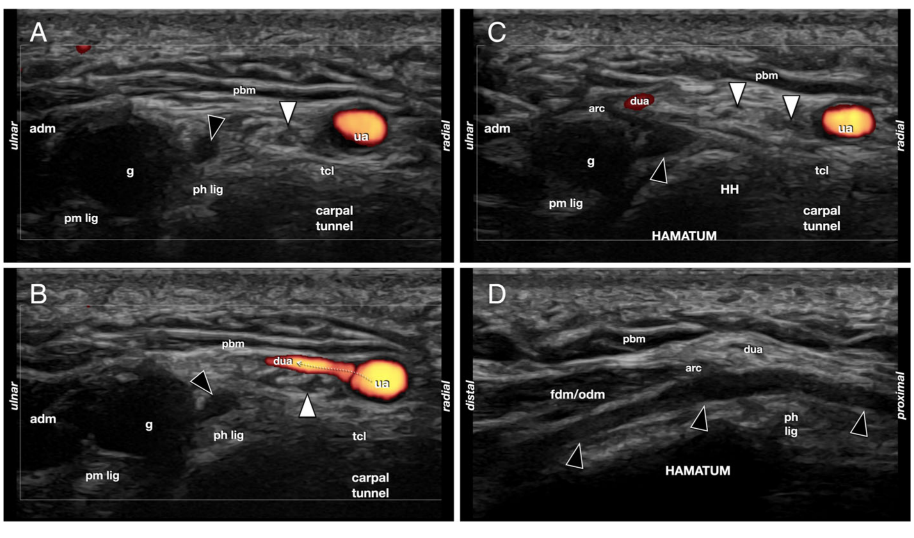
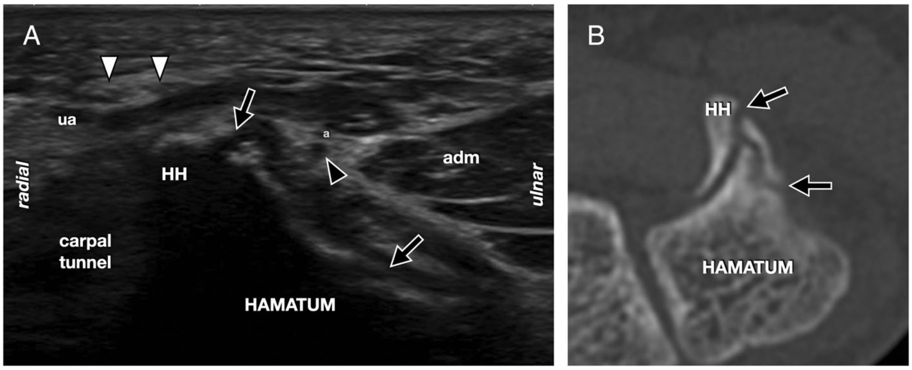


**Figure 26.** Hamate fracture. Patient with a trauma of the ulnar side of the wrist/hand. US was requested due to persistent pain. The x-ray (not shown) was reported as normal. **A**, Axial ulnar sonogram of the distal Guyon's canal demonstrates irregularities (black arrows) of the hook of the hamatum (HH). Note the close proximity of the DBUN (black arrowhead) and the concomitant artery (a), whereas the SBUN (white arrowheads) is a bit more distal to the fracture. There was clinically no involvement of the nerve. **B**, Axial CT confirmed the fracture of the hook of the hamatum. Adm, abductor digiti minimi muscle; ua, ulnar artery.




In pisotriquetral joint disorders, particularly osteoarthritis, joint effusion may irritate the UN or its branches at the canal[57–59]; as can ganglion cysts.[60] These cysts may also arise from the triquetro-hamate joint or, more rarely, the ulnocarpal or other carpal joints.[60,61] US can finely depict nerve enlargement near the avascular cyst, whereas MRI may be more accurate than US for demonstrating its articular origin.[58] In our experience, a ganglion cyst at the Guyon's canal can cause relevant nerve compression, particularly when the cysts are located near the hook of the hamate, due to the narrow space where the DBUN passes the pisohamate hiatus under the fibrous arcade of the hypothenar muscles (Figure 25).[61,62] Moreover, US can be a guide to aspiration and/or injections in these cases.[63]

A pisiform-hamate coalition has been reported to possibly compress the DBUN.[64]

Recently, an anomalous course of the DBUN inside the carpal tunnel, diagnosed with US, has been described as a rare possible cause of neuropathy.[62]

Masses, such as lipomas, may rarely compress the nerve.[65–67]

Accessory muscles, such as the accessory digiti minimi described in part 1, are reported to possibly cause neuropathy[68]; we believe that this variant is almost always an asymptomatic finding.[1]

Hamate fracture may lead to neuropathy of the UN branches, due to the nerve's proximity (Figure 26).[69] The SBUN and the DBUN should therefore be carefully evaluated.[61]

Repetitive microtrauma (Figure 27), as in sports like cycling, is reported to possibly determine UN palsy.[70,71] High-frequency US (with transducers at least up to 18 MHz) has been proven to be a valid tool with which to demonstrate the affected branch/es.[71] MRI has also been studied to demonstrate a change in the position of both the SBUN and DBUN with respect to the hook of the hamate related to wrist position, which may promote pathology in cyclists.[72]

**Figure 27.** UN compression at distal Guyon's canal. The patient, a professional bicyclist, presented with dysesthesia of the two ulnar fingers occurring after long-distance bicycling. No motor weakness was present. Axial sonogram of the wrist at the level of the hook of the hamate (HH) demonstrates the enlargement of the branches of the SBUN (black arrowhead), whereas the DBUN (open arrowhead) appears more preserved, which is suggestive for SBUN compression due to repetitive compression of the nerve against the HH. Adm indicates the abductor digiti minimi muscle; tcl, transverse carpal ligament; ua, ulnar artery.

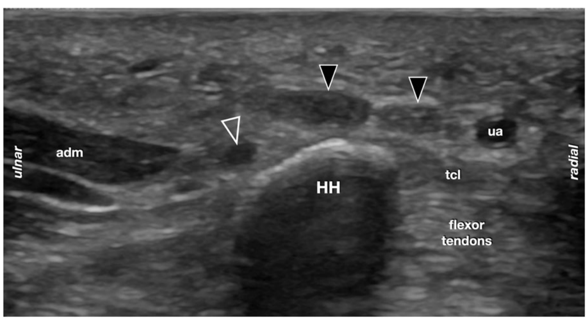
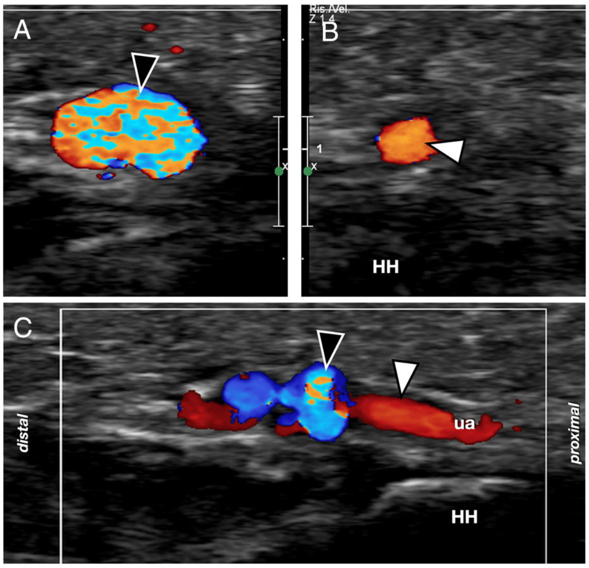


**Figure 28.** Hypothenar hammer syndrome. Aneurysm of the ulnar artery. **A**–**B**, Axial color Doppler sonograms distal (**A**) and at the level (**B**) of the hook of the hamate (HH) of the ulnar artery (ua) in a manual worker. The artery is enlarged in (**A**) (black arrowhead), whereas it is normal in (**B**) (white arrowhead). **C**, Corresponding long-axis of the artery. Note the enlargement just distal to the hook of the hamate. Patient had no clinical and no sonographic sign of UN involvement.




Hypothenar hammer syndrome is related to repetitive microtrauma too, leading to thrombosis and/or aneurysm of the ulnar artery (Figure 28); the nerve may be possibly compressed as well.[73]

## Conclusion

US is an excellent modality to demonstrate pathological changes of the UN.

Recent high-frequency transducers can capture fine details, which is particularly important when evaluating the distal branches of the UN. It is mandatory to be familiar with the normal anatomy and possible pitfalls based on variants, as described in part 1 of this two-part article.[1] Pathological findings observed with US require correlation with the clinical scenario and electrodiagnostic tests.

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## Data Availability Statement

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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