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Usefulness of Ultrasound in Hand Surgery: Part II

Utilidad de la ecografía en la cirugía de la mano: Parte II

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Abstract

In the last years, with the technical advances in ultrasound, image quality has improved, which has enabled surgeons to enhance their ability to perform hand and wrist evaluations. Ultrasound-guided infiltrations in hand surgery are more precise and safer compared to those not guided by ultrasound. The development of the ultrasound technique and of high-resolution transducers helps us to perform ultrasound-guided procedures, such as the treatment of trigger finger, carpal tunnel syndrome release and aponeurotomy in Dupuytren disease. The aim of the present paper is to describe the ultrasound techniques used in the treatment of hand disorders and the state of the art in ultrasound-guided hand surgeries and their outcomes.

Keywords
- ultrasound-guided surgery
- minimally-invasive hand surgery

Resumen

En los últimos años, con los avances técnicos en la ecografía, aumentó la calidad de las imágenes, lo que ha permitido a los cirujanos mejorar su capacidad de evaluar la mano y la muñeca. Las infiltraciones ecoguiadas en cirugía de mano son más precisas y seguras en comparación con las infiltraciones sin el uso de ecografía. El desarrollo de la técnica de ecografía y de transductores de alta resolución nos ayuda a realizar procedimientos ecoguiados, como el tratamiento del dedo en gatillo, la liberación del síndrome del túnel carpiano, y la aponeurotomía en la enfermedad de Dupuytren. El objetivo de este trabajo es describir las técnicas ecográficas en el tratamiento de las patologías de la mano y el estado del arte de las cirugías ecoguiadas de la mano y sus resultados.

Palabras clave
- cirugía guiada por ultrasonido
- cirugía mínimamente invasiva de la mano

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General Guidelines for Ultrasound Infiltration

Ultrasound-guided injections are performed in the hand surgery practice. All the tendons, joints and many other structures can be identified by ultrasound (US). We can use IS in many different pathologies, such as trigger finger, De Quervain disease (DQd), and carpal tunnel syndrome (CTS).

The advantages of US-guided infiltration are:[1]

- Accurate needle placement and delivery of the drug into the joint or structure.
- Less uncomfortable for the patient.

The tips for effective US-guided joint and tendon injections are:[1]

- A full aseptic technique is required. You can use Betadine gel (Avrio Health, Stamford, CT, United States) instead of normal US gel.
- Careful planning and positioning before needle insertion will make the procedure easier and safer.
- The needle path should be carefully chosen to avoid injury to vessels, nerves, and tendons.
- Align your transducer along the chosen path. Angle your needle along the same path as the transducer.
- Anesthetizing the skin is optional.
- The depth of the joint will influence the angle of insertion of the needle, and you will advance the needle slowly under ultrasound guidance. Take your time to find the location of the tip of the needle.
- When the needle pierces the joint capsule, the patient may experience mild discomfort (a little amount of anesthetic can be injected to avoid pain).
- You can use an in-plane or out-of-plane approach.

  a) For an in-plane approach: the needle tip will lie along the line of the transducer, enabling full view of the needle track. This is the easier technique to learn.
  b) The out-of-plane approach, in which the needle is inserted in the side rather than the end of the transducer, is slightly more difficult to learn and perform, but is useful in certain situations.

The surgeon must check both planes, transverse and longitudinal, also called short axis and long axis, when performing an ultrasound infiltration, to ensure that the tip of the needle is in the right place.

- Once the needle tip is in a good position, the injected fluid should flow easily. Sometimes the needle is inside a tendon or against the bone. Just withdraw the needle slightly by 1 mm to 2 mm, recheck the position, and continue with the injection.
- For the hand, a higher frequency transducer (12–18 MHz) or a small hockey-stick transducer is preferred. We recommend a 25G hypodermic needle for the smaller joints (wrist, hand), and a 28G hypodermic needle for the finger joints.

The technique is the same in procedures such those performed for trigger finger, DQd, or CTS. Only the anatomy will change but the procedure, as previously described, will be similar.

Trigger Finger

Trigger finger is a pathologic condition of the digital pulleys and flexor tendons. The lifetime occurrence rates are of 2.6% among healthy individuals and of 10% among diabetics.[2] It affects women more than men (in the fifth and sixth decades of life),[2] and involves the ring finger, middle finger, and thumb.[2]

The diagnosis of trigger finger is based on the medical history and clinical findings: a transient blockage of the digit when it is flexed with subsequent painful snapping when it is extended. Trigger finger typically occurs due to thickening of the A1 pulley at the level of the metacarpophalangeal joint.[3] Thickening of the A1 pulley narrows the digital osseofibrous tunnel through which the flexor tendons run, impairing tendon gliding.

Clinically, this results in different stages of disease according to the classification by Green and Wolfe:[3,4]

- Grade 1: includes local pain and a history of entrapment;
- Grade 2: demonstrable entrapment with normal active extension;
- Grade 3: demonstrable locking requiring passive extension; and
- Grade 4: fixed flexion deformity.

The US is a helpful guide to establish the severity of the disease, identify the underlying cause, and decide the appropriate treatment options, which include conservative therapies, such as splinting, anti-inflammatory medications, US steroid injections, and US surgical pulley release.[2,3,5,6]

Examination Technique, Normal Ultrasound Appearance[2,3]

For the US examination, the dorsal surface of both hands rests on the exploration table. The fingers are kept in full extension.

The examination is best performed with high-resolution transducers working at 18 MHz and a large amount of coupling gel.

The annular pulleys can be visualized with US under healthy conditions:

On transverse view or in the short axis, the central part of the annular pulleys appears as a fibrillar echoic structure that lies superficial to the flexor tendons. Their lateral bands are not perpendicular to the US beam and appear as hypoechoic bands at both sides of the tendon secondary to anisotropy.
On longitudinal view or in the long axis, the annular pulleys appear as linear thickening of the flexor tendon sheath and often appear hypoechoic because of anisotropy.

Ultrasound Appearance of Trigger Finger[2,4]

On US imaging of trigger finger, there is a global or nodular hypoechoic thickening of the affected A1 pulley. It is best assessed on transverse scans in comparison with the normal pulley of the adjacent unaffected digit.

The thickness of the A1 pulley measured through US has shown a strong correlation with the thickness assessed intraoperatively. A cutoff value of 0.62 mm has been recently described to distinguish the thickness of the A1 pulley of trigger digits from that of healthy digits in adults, regardless of age, gender, height, and body mass index.[2,5]

Thickening of the A1 pulley is greater in patients with contracture of the proximal interphalangeal joints of the thumb or fingers, as compared with patients without any contracture.[2,4,5]

On Doppler imaging, hyperemia of the affected A1 pulley has been observed in 91% of the cases.[4]

Secondary causes of trigger finger, such as an exostosis, can be identified through US.[4]

The underlying flexor tendons often become swollen and, on a transverse scan, their cross-sectional area is rounder and thicker. The superficial flexor tendon is the first to be affected, as it impinges on the inferior aspect of the A1 pulley during finger flexion. The thickness of the flexor tendon under the A1 pulley depends on the severity of the triggering. In the acute stages, synovial sheath effusion develops and is more evident proximal to the thickened pulley: (►**Figs. 1A, B, C, and D**).

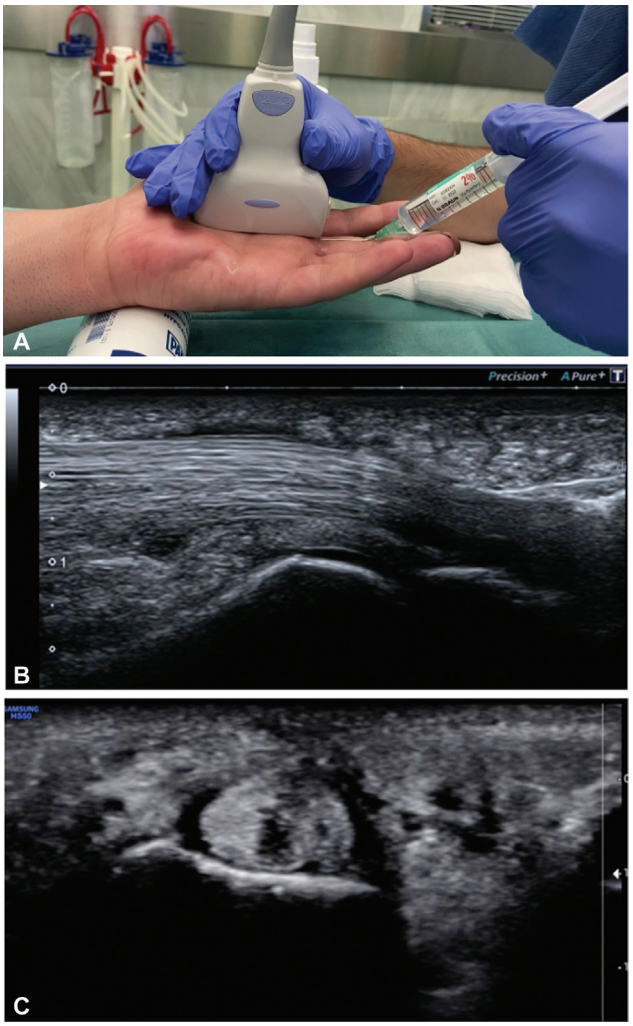

Fig. 1 (**A, B, C**) Infiltration of trigger finger. In-plane infiltration of the third finger. Ultrasound (US) showing in-plane and out-of-plane trigger finger infiltration.

Technique for Percutaneous Release of Trigger Finger by Ultrasound[2,5,6]

We have performed these procedures using a high-frequency transducer (18 MHz).

The patient was placed in supine position with the hand flat on a table. A sterile working area is prepared and a sterile probe cover and US gel or betadine gel are used. We also apply extra gel on the finger, between the transducer and skin, to make it easier to locate the needle.

First, a local anesthetic is inserted with a 25-mm long, 25G needle. The entry point is in the proximal third of the proximal phalanx, and the needle is directed toward the distal part of the A1 pulley.

Two milliliters of lidocaine 1%/adrenaline 1:100,000 are injected along the needle's path and into the synovial sheath of the flexor tendons.

Next, the base of a 50-mm long, 21G needle is manually curved to a 140° angle so that its bevel faces laterally. This curvature has two effects: it places the needle in a completely horizontal position and makes it possible to determine the bevel's orientation even when it is fully inserted.

Once the 21G needle is in the desired location, the surgeon slides it back and forth horizontally, parallel to the long axis of the flexor tendons, along the trajectory of the A1 pulley, several times. You can feel the typical slight resistance of the structure being cut (A1 pulley).

During the release, continuous US monitoring of the position of the needle is performed in the long axis, also checking the position of the needle in the short axis of the tendon. A centrally located needle ensures that we are far away from the interdigital neurovascular bundle and that the release will be more effective.

Once these back-and-forth movements are completed, the needle is removed, and the patient is asked to actively flex and extend the treated finger. If the triggering has disappeared, the procedure is considered complete. If moderate triggering remains, the 21G needle is reinserted and the back-and-forth movements are repeated several times.

Performance of US-guided release in the thumb is technically more difficult than in the long fingers. A continuous monitoring in both the short and the long axis will prevent any damage of the tendon or neurovascular structures: ►**Fig. 2**.

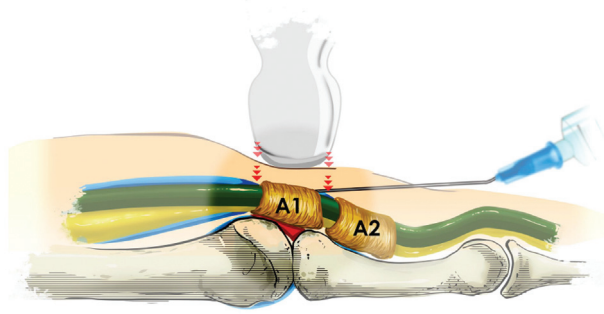

Fig. 2 Ultrasound percutaneous release of trigger finger. Relationship between the needle and A1 pulley.

After the procedure, a rest period of 8 to 10 hours may be advisable, as well as and avoiding lifting weight with that hand for several days to prevent pain and edema.

The results of US percutaneous trigger finger release have been demonstrated: Rajeswaran et al.,[7] with a follow-up of 6 months in 35 cases, showed that the trigger finger was completely resolved in 91% (32 of 35) of the cases, and no complications were observed. Jou and Chern[8] conducted a larger study (104 fingers), in which a specially-designed hook (2.5 mm) was used during the US-guided release; The patients were seen again 9 to 15 months later; the mechanical problem had resolved in 100%, and the pain had disappeared in 97% (101 of 104) of the cases. Sometimes there is a persistence of isolated, nonspecific, nondisabling pain in 3% of fingers. Jou and Chern[8] found the same rate in their study.

De Quervain Disease

Regarding radial wrist pain, DQd is a common differential diagnosis. Ultrasound may help to confirm the clinical diagnosis,[9,10] the detection of anatomical variants, and the presence of alterations that represent a prognostic factor in the evolution of the process.

Regarding treatment, the introduction of the US guide provides more precision and efficiency to the infiltrations.

Choi et al.[11] compared the result of the ultrasound study with the intraoperative findings and established a diagnostic sensitivity of 100% ►**Fig. 3 (A, B, C)**.

The diagnosis of DQd is defined by the following US criteria:[12,13]

1. Hypoechoic thickening of the extensor retinaculum of the first extensor tunnel;
2. Increased Doppler signal;
3. Thickening of the tendons distal to the retinaculum (adductor pollicis longus and extensor pollicis brevis);
4. Peritendinous effusion; and
5. Absence of findings suggestive of intersection syndrome, CTS or radiocarpal arthropathy: ►**Fig. 4 (A, B)**, ►**Fig. 5 (A, B, C, D)**, and ►**Fig. 6 (A, B)**.

Of all these findings, the thickness of the retinaculum is probably the most important.[12]

Recent studies[14–16] have determined that US has a sensitivity of 97.9% and a specificity of 91.6% to identify the presence of subcompartments. False positives have been identified in previously-infiltrated patients in whose case the crystallization of corticoid derivatives can generate hypoechoic images in the tendon sheath that simulate septation.[14]

Volpe et al.[16] proposed a differentiation into two types of DQd based on US findings:

- Type I: thickening of the entire retinaculum that surrounds the abductor pollicis longus (APL) and extensor pollicis brevis (EPB). ►**Fig. 7**
- Type II: selective thickening of the retinaculum at the level of the EPB. ►**Fig. 8**

The only difference observed between groups was that the type-I patients were older, so we did not consider the classification useful, as we cannot establish prognostic factors.

The *treatment of DQd* includes conservative therapies, such as splinting, anti-inflammatory medications, ultrasound steroid injections, and surgery when these conservative treatment fails.

There is level-I evidence that glucocorticoid infiltration associated or not with splint immobilization is superior to

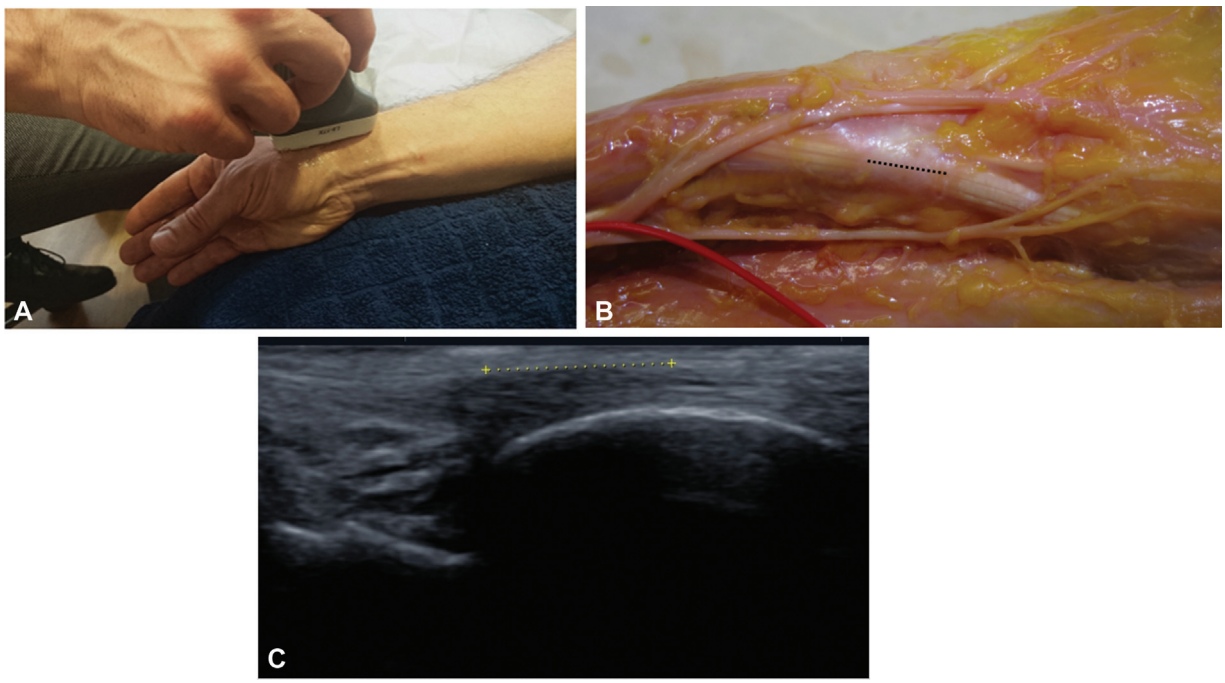

Fig. 3 (**A, B, C**) First extensor compartment. Longitudinal US probe showing the extensor retinaculum and tendons. Correlation between US and anatomy dissection.

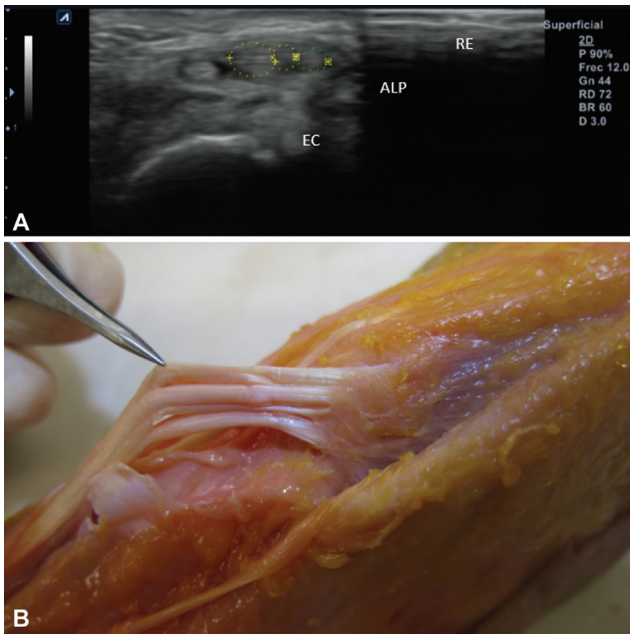

Fig. 4 (**A**, **B**) First extensor compartment. Axial US probe showing the extensor retinaculum and tendons of extensor pollicis brevis (EPB), abductor pollicis longus (APL), as well as accessory tendons. Correlation between US and anatomy dissection.

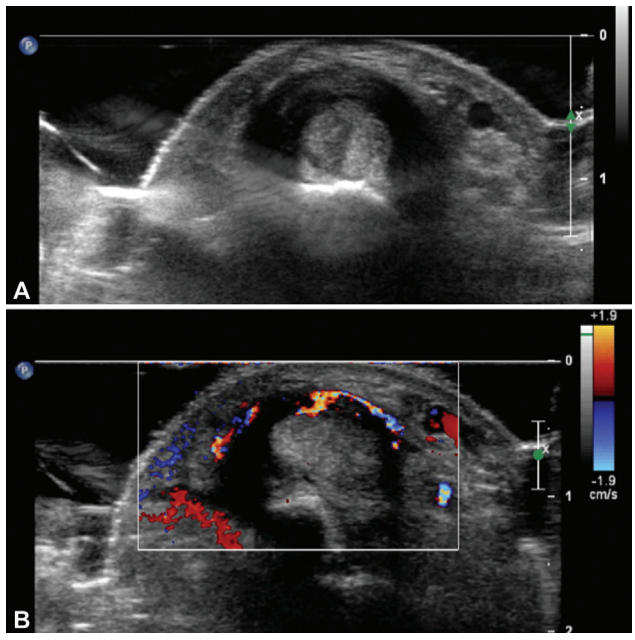

Fig. 6 (**A**, **B**) De Quervain disease with hypoechoic thickening of the extensor retinaculum of the first extensor tunnel and increased Doppler signal.

isolated immobilization, making it the recommended initial option for the treatment of DQd with resolution rates between 62% and 100%.[17–20]

Cadaveric studies[18] have shown a US-guided infiltration accuracy of 93.3% even in the presence of septa. On the other hand, the technique based on anatomical references presents an overall precision of 40% and of only 16.7% in wrists with subcompartments.[19,20]

McDermott et al.[19] described symptomatic improvement at 6 weeks in 97% of the cases and resolution (improvement of at least 80%) in 92% of the cases. At the end of the follow-up, the mean scores on the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire and Visual Analog Scale

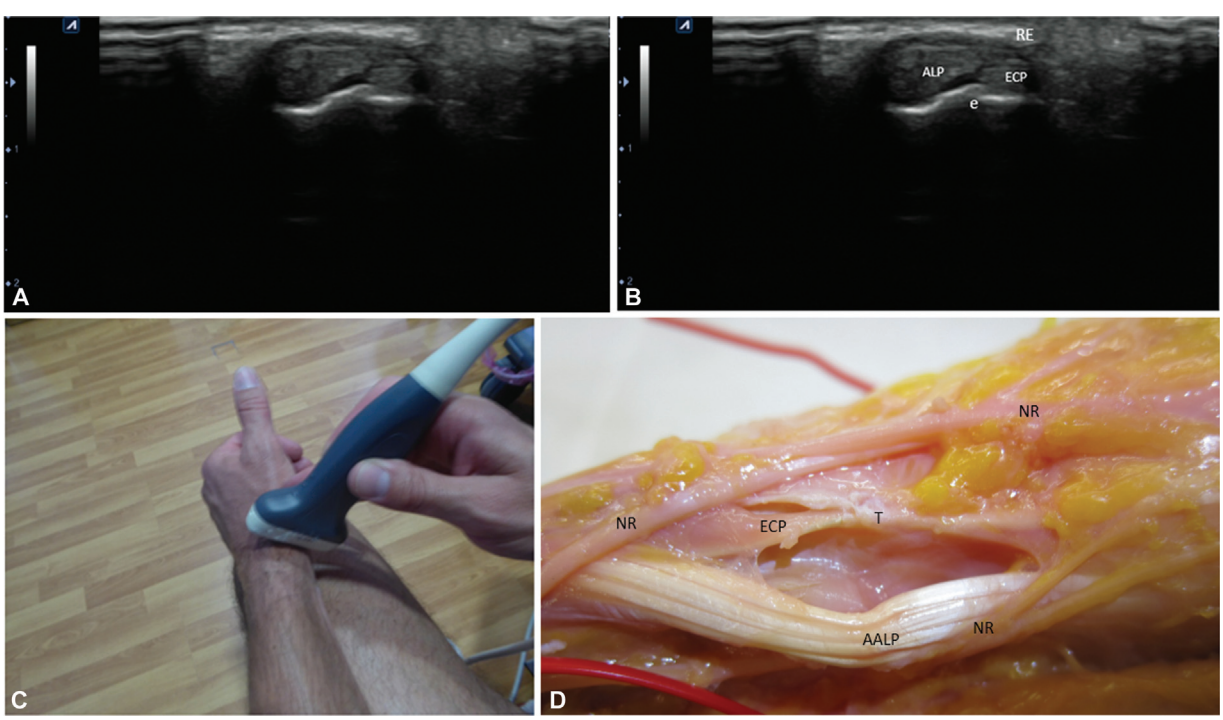

Fig. 5 (**A**, **B**, **C**, **D**) First extensor compartment. Axial US probe showing first extensor compartment with an intercompartmental septum and correlation with anatomical dissection.

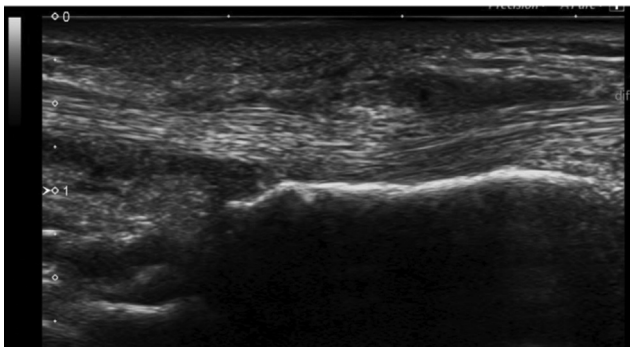

Fig. 7 First extensor retinaculum thickening in De Quervain disease.

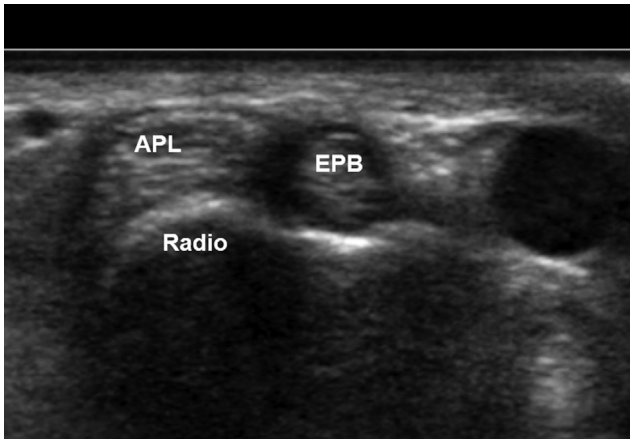

Fig. 8 Selective affection of EPB tendon. Hypoechoic area surrounding the EPB tendon.

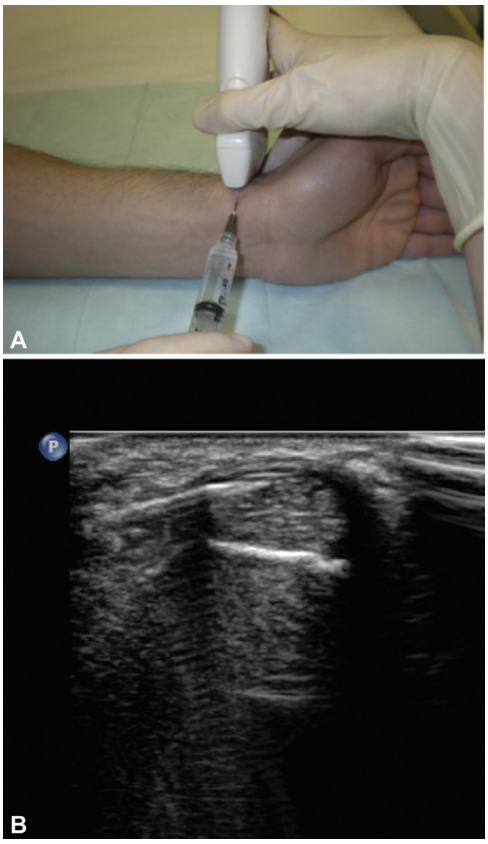

Fig. 9 (**A, B**) Transverse in-plane infiltration of first extensor compartment in De Quervain disease.

(VAS) wereof 18.39 and 2.2 respectively, with recurrence of symptoms in only 14%. These results are slightly higher than those of the series of infiltrations without the use of US.[19]

A clinical trial performed by Kume et al.[20] demonstrated the superiority of US-guided infiltration to techniques based on anatomical landmarks in cases with intracompartmental septa ►**Fig. 9 (A, B)**, ►**Fig. 10 (A, B, C, D)**.

Carpal Tunnel Syndrome

The most frequently diagnosed nerve entrapment syndrome is CTS (3.8 cases for every 1,000 individuals in the general population).[21–23]

It affects from 1 to 2/1,000 men and 4 to 5/1,000 women, is more frequent in patients between 40 and 60 years of age,[21] and occurs in 14% of diabetics who do not have polyneuropathy and in 30% of those with clinical polyneuropathy.[23] The incidence of CTS during pregnancy varies from 7% to 62% according to one study,[23] and in most of the cases it regresses after birth.

When the medical treatment fails, or in severe cases, surgical treatment becomes a necessity.

Surgical intervention generally resolves the symptoms, or at least prevents further clinical deterioration and the development of motor deficit.

Surgical treatment of the carpal tunnel is one of the most frequently performed procedures. The number of interventions to release the median nerve in the carpal tunnel has increased considerably since the early 1990s.

Presently, there are two main surgical techniques:[24–27] open surgery (referred to as conventional or mini-open surgery) and the endoscopic treatment. While the rate of major complications is low irrespective of the surgical technique used, the time until return to work is shorter after the endoscopic treatment compared with open surgery.[24]

Lately, US-guided release has assumed an increasingly prominent role in the treatment[25–28] and investigation of secondary etiologies.

The first applications of US surgery for CTS were described by Nakamichi more than 30 years ago. Since then, several studies have highlighted the potential of a minimally-invasive technique with US guidance to transect the flexor retinaculum (FR).[28–30]

Diagnosis of CTS

The diagnosis of CTS[22] is clinical.

An electromyogram (EMG) is a useful procedure, although it is not indispensable for the diagnosis.[21] A comparison of US and EMG indicates that, depending on the study, they are largely identical in terms of sensitivity and specificity, although US has the advantage of enabling the analysis of the anatomical structures and the nerve itself.[21] Better tolerated, US also costs less than an EMG.[21]

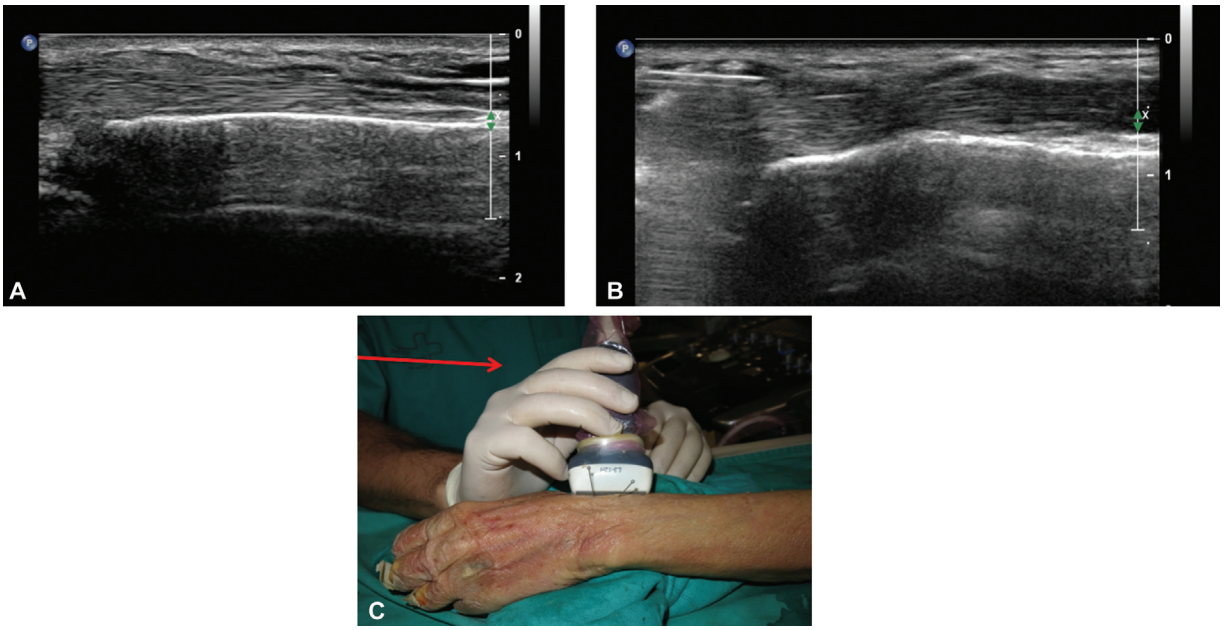

Fig. 10 (**A, B, C, D**) Longitudinal in-plane infiltration of first extensor compartment in De Quervain disease.

On the other hand, US does not enable the evaluation of the nature of the functional impact on the nerve (sensory or motor).

MacDonagh et al.[25] recently highlighted a new role of US in the diagnosis and treatment of the carpal canal. They investigated multiple US parameters, of which bulging of the receptacle flexor, thickening of the retinaculum, and alteration of the echogenicity of the median nerve are deemed the most relevant.[25]

The increase in the cross-sectional area of the median nerve at the level of the proximal carpal tunnel (scaphoid-pisiform plane) is the most conventional parameter, and it varies from 6.5 mm^2 to 13 mm^2 depending on the study.[26] However, there is a lack of consensus regarding the limiting values to be assigned to it. More specific parameters have also been described, such as the difference or ratio of the cross-sectional area of the median nerve at the proximal carpal tunnel and the distal third of the forearm (at the pronator muscle). Klauser et al.[26] recently evaluated the relevance of these two measurements to predict the severity of CTS in a population for whom the diagnosis had been confirmed clinically and by EMG.

However, the diversity of the US criteria used in these studies limits the ability to compare them, and the latest validated criteria that appear to be the most sensitive and specific have not yet been used.

Lastly, at the therapeutic level, interventional US provides guidance for carpal tunnel injections that makes the procedure safer and prevents complications due to intraneural injection.[25] However, the benefit of US guidance on the efficacy of injections has not been shown.

Ultrasonography has become a readily-accessible low-cost procedure that is an immediate extension of the clinical examination. The carpal tunnel is studied using a lineal probe that enables its visualization by sweeping the probe over the trajectory of the median nerve.

On *axial view*,[25,26,29] the nerve presents as an fascicled oval structure; the nerve bundles are hypoechogenic regardless of the orientation of the US beam to the bundle. This helps distinguish the nerve from the tendons that surround it, with a fibrillar structure alternating from hypo- to hyperechogenic according to the orientation of the probe: ►**Fig. 11 (A, B, C)**, ►**Fig. 12 (A, B)**, and ►**Fig. 13 (A, B)**.

Inside the tunnel, one tip to find the median nerve is to look for the flexor carpi radialis (FCR) tendon over the scaphoid and de flexor pollicis longus (FPL) tendon. The median nerve is always superficial and ulnar to the FPL and ulnar to the FCR.

On *longitudinal view*,[25,26,29] the median nerve presents as hypoechogenic strips that run parallel to each other. Its diameter is constant or decreases slightly and progressively along its intracanal trajectory. The nerve runs between the FR and the superficial flexor tendons of the second and third digits.

Several anatomical layers of the FR have been described. The more superficial layer is continuous with the antebrachial fascia and can be its reinforcement, while the deeper layer is akin to a ligament (the transverse carpal ligament).

Surgical Treatment

The *surgical treatment*[29] is based on fully opening the FR to decompress the nerve. However, selective section of the deep layer may enable the preservation of the mechanical functions of the FR and the highly-innervated layers to be spared.

Ultrasound Surgery of the Carpal Tunnel

Technological advances have led to the use of US guidance to improve CTS treatment. Ultrasonographic determination of the relative position of the retinaculum with the neural and vascular structures in relation to the bony landmarks correlates well with the actual anatomy.[27–39]

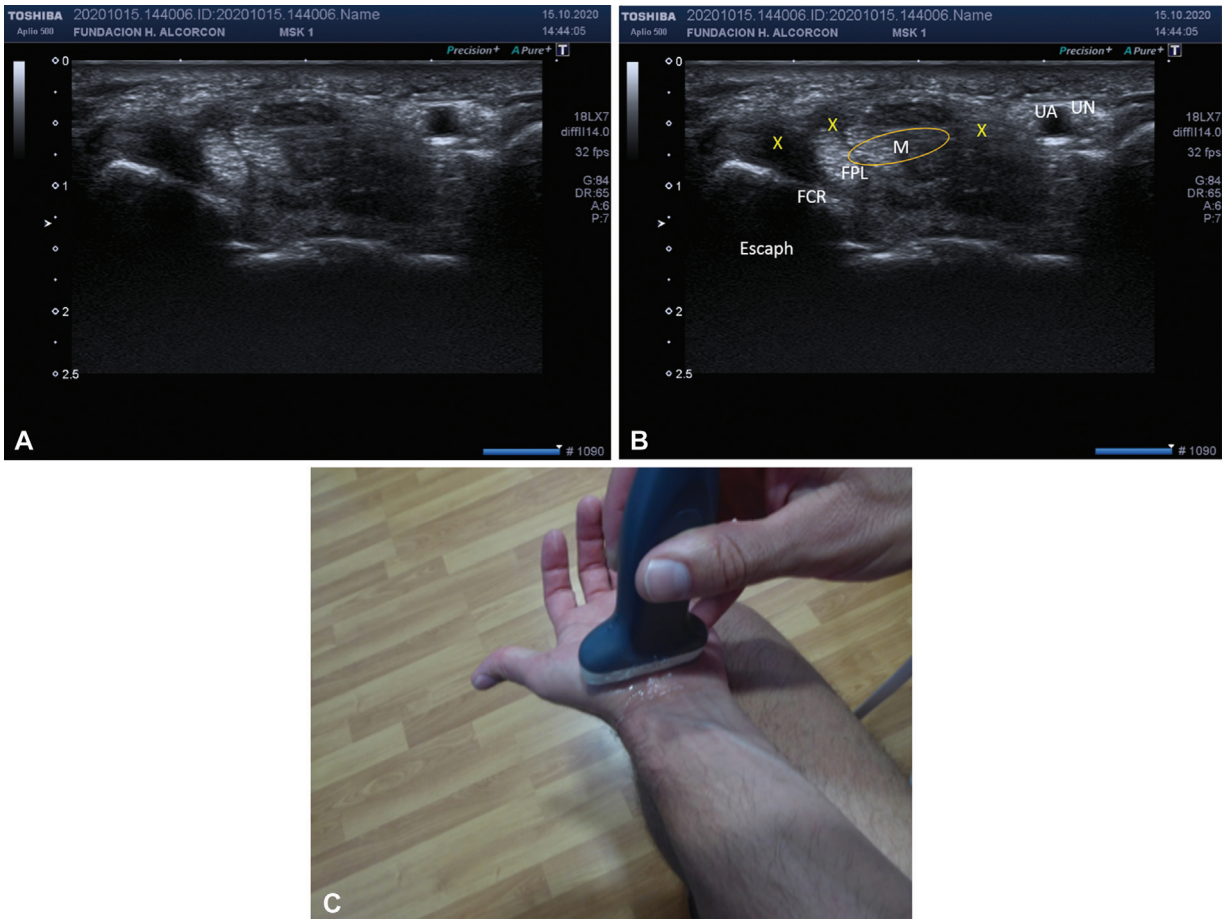

Fig. 11 (**A, B, C**) Transverse view of the carpal tunnel before and after the establishment of anatomical landmarks. We can see the different structures. Abbreviations: FCR, flexor carpi radialis; FPL, flexor pollicis longus; M, median; P, pisiform; Scaph, scaphoid; UA, ulnar artery; UN, ulnar nerve; XXX, flexor retinaculum.

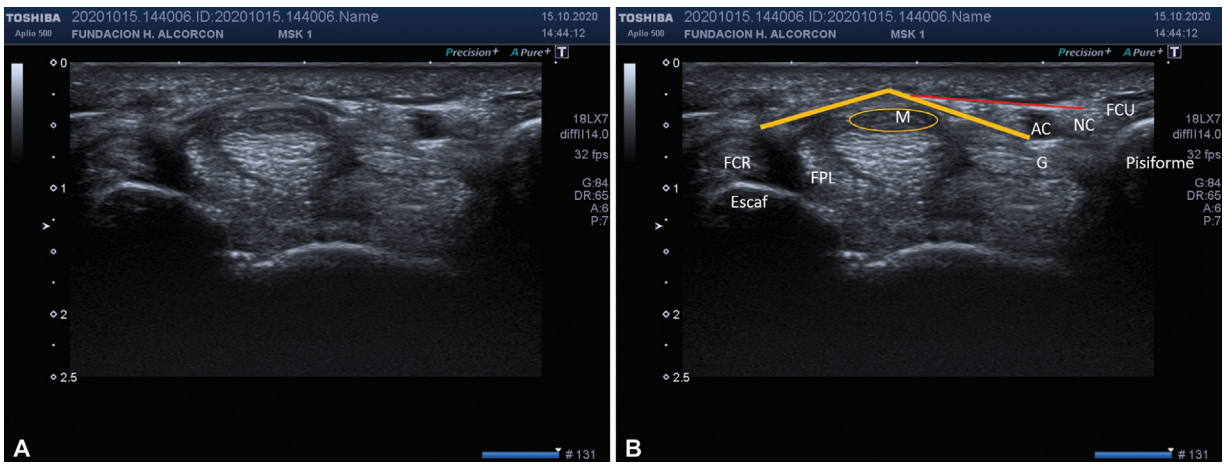

Fig. 12 (**A, B**) A more distal view. Transverse view of the carpal tunnel before and after the establishment of anatomical landmarks. We can see the different structures. Abbreviations: FCR, flexor carpi radialis; FPL, flexor pollicis longus; M, median; P, pisiform; Scaph, scaphoid; UA, ulnar artery; UN, ulnar nerve.

In 1997, Nakamichi and Tachibana [27] proposed making use of US guidance during the conventional surgical intervention. This first description was more a US-assisted surgery than a US-guided surgery. Over time, several studies[30–35,37,38] were able to demonstrate that it is possible to perform the whole procedure guided by US.

The location of a "safe-zone" between the median nerve and the ulnar artery for the section has been clearly demonstrated by Chern et al.[29]

Location through US of the target structures facilitates the safe and efficacious resection of the FR. Recent anatomical and clinical studies[29,36] suggest that complete release of the

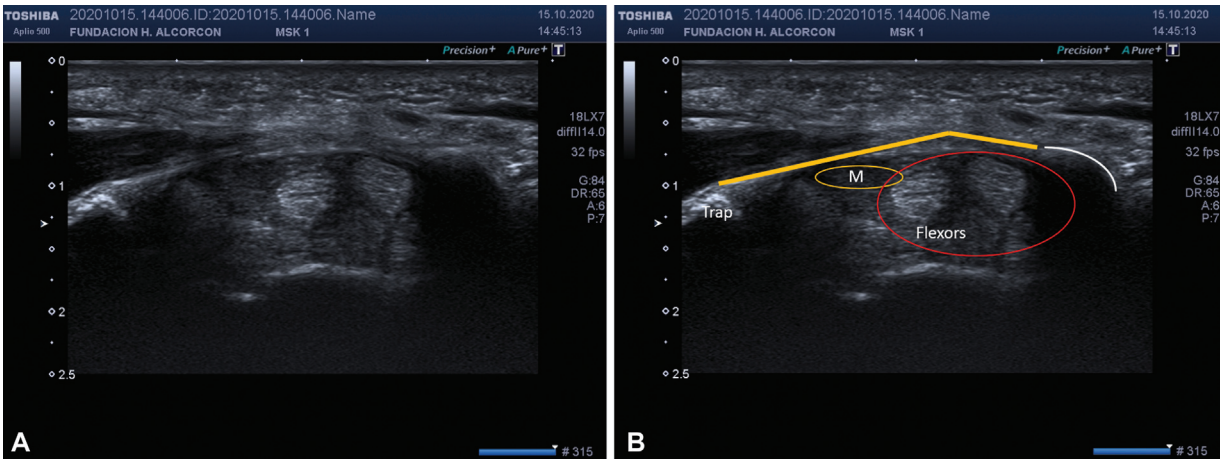

Fig. 13 (**A, B**) Distal view at the trapezoid insertion of the flexor retinaculum. Abbreviations: M, median; Trap, trapezium.

nerve is possible through section of only the deep fibers of the FR without cutting the superficial fibers. The superficial layer is more richly innervated, and sparing it by not sectioning it should enable the avoidance of local postoperative pain.

The foremost justification for the development of this new technique is its minimally-invasive nature. An open surgery or limited approach requires an opening of more than 4 cm to 5 cm, the mini-open surgery involves an incision of 2 cm, and the endoscopic treatment employs an opening of 1 cm to 2 cm.[31] Ultrasound surgery enables the performance of an incision that is up to ten times smaller, ranging from 0.1 cm to 0.5 cm with continuous vision of the nerve and surrounding structures.[30–32]

The comparison of surgical procedures in terms of the size of the approach route indicates that the smaller the incision, the quicker the return to work. Not surprisingly, the esthetic and functional consequences of the surgical scar are also more limited with a smaller incision.[31–35,37]

Indeed, Jugovac et al.[36] observed that, compared with a conventional open approach, a mini-open incision decreased the time until return to work by half (that is, 15 days versus 30 days). Therefore, US surgery appears to combine a decrease in the size of the incision with an excellent surgical field of view through continuous image-based guidance.

The ultra-minimally-invasive US surgery can be performed as an outpatient procedure, and it can be performed outside the operating theater, such as in an interventional radiology room or in an office, as previously reported.[31–41] We prefer to perform this technique in the operating room.

In 2016, we presented our technique on the website of the American Academy of Orthopaedic Surgeons (AAOS)[30] using a systematic approach useful for other US-guided surgeries.

The patient is placed lying down in supine position, without a tourniquet, under strict antiseptic conditions.[30]

We use a 25G and then a 21G needle, a V-shaped curette of two sizes, as well and an Acufex 3.0 mm hook knife with a retrograde blade (010600; Smith & Nephew PLC, London, England). We only provide local anesthesia to the median nerve with lidocaine 1%/adrenaline 1:100,000.[30]

First, an US scan is performed to locate the safe zone between the ulnar artery and the median nerve as described by Nakamichi et al.[28] The possibility of a variant of the thenar motor branch needs to be systematically checked through the US. Certain variants originating from the ulnar nerve or those with a trajectory that perforates the retinaculum are more at risk of iatrogenic lesion. The position of the vascular arch is also ascertained[29,30] ►**Fig. 14A, B, C**.

A first subcutaneous anesthetic is administered at the proximal crease of the wrist, while a second deeper one with 10 mL of lidocaine 1%adrenaline 1:100,000 enables the hydrodissection of the carpal tunnel:[30] ►**Fig. 15A, B, C** and ►**Fig. 16**.

A small curette is used over the needle to penetrate the antebrachial fascia and later enable the hook knife to enter the fascia and retinaculum. The hook knife must be placed under the junction of the antebrachial fascia and the retinaculum. The knife is steadily advanced under the FR with continuous US monitoring, with the knife facing the ulnar artery, while taking care to avoid the median nerve and the origins of the sensory branches, as well as the Berrettini branch. The hook is advanced until 2 mm to 3 mm from the palmar arch, then it is turned vertically. A back-and-forth movement enables the tip of the hook knife to perforate the fibers of the retinaculum. Then, the retinaculum is sectioned in a retrograde manner with continuous US monitoring. It has been shown[30–33,38,39] that complete CTS relief is not achieved until joint release of the transverse carpal ligament and the distal part of the deepest fibrous layer: ►**Figs. 17**, **18**, **19 (A, B, C)**, **20 (A, B)**, **21 (A, B)**.

The full procedure can be performed in 15 to 20 minutes. A preventative compression bandage is applied, rest is recommended, and simple analgesics upon request are recommended, although not systematically. The patient can return to home within an hour of the procedure. The compression bandage is removed 24 to 48 hours after the surgery. No sutures are needed at the end of the procedure.[30]

Comparison of the Techniques

Surgical advances have enabled a progressive decrease in the size of the approach (conventional open surgery in the order of 5 cm, mini-open in the order of 2 cm, and endoscopy in the

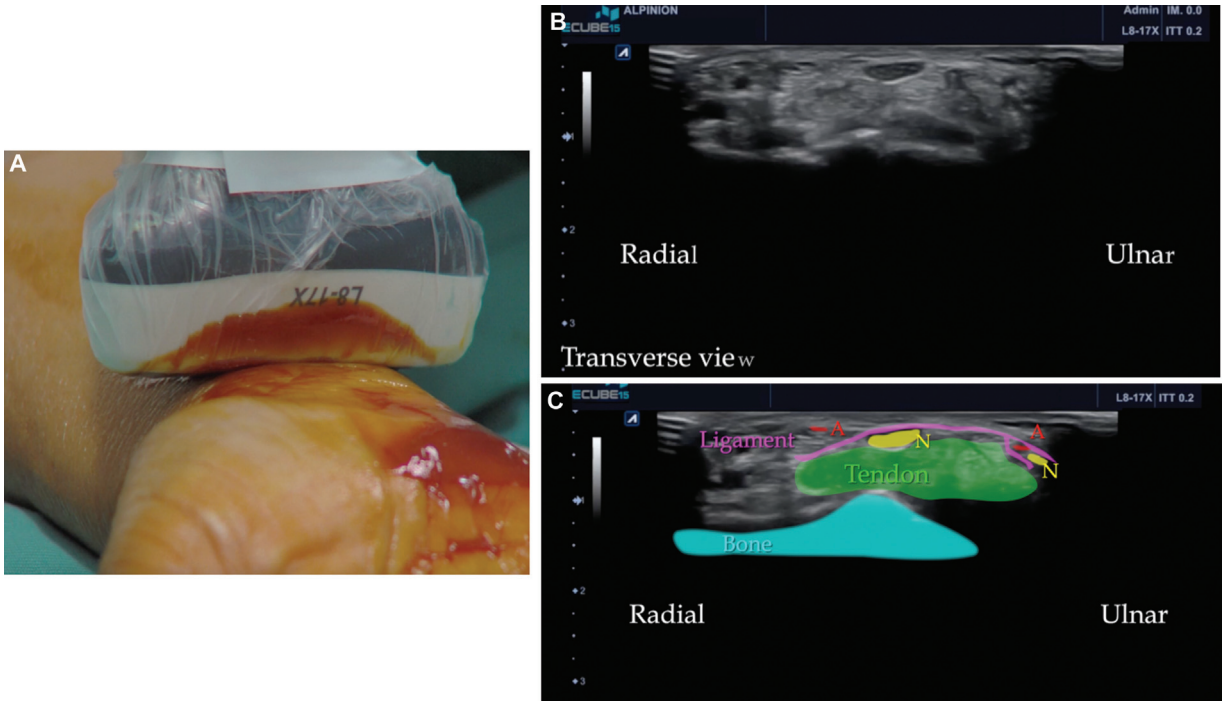

Fig. 14 (**A**, **B**, **C**) Carpal tunnel syndrome (CTS) surgery. Transverse view with the probe and location of the safe zones.

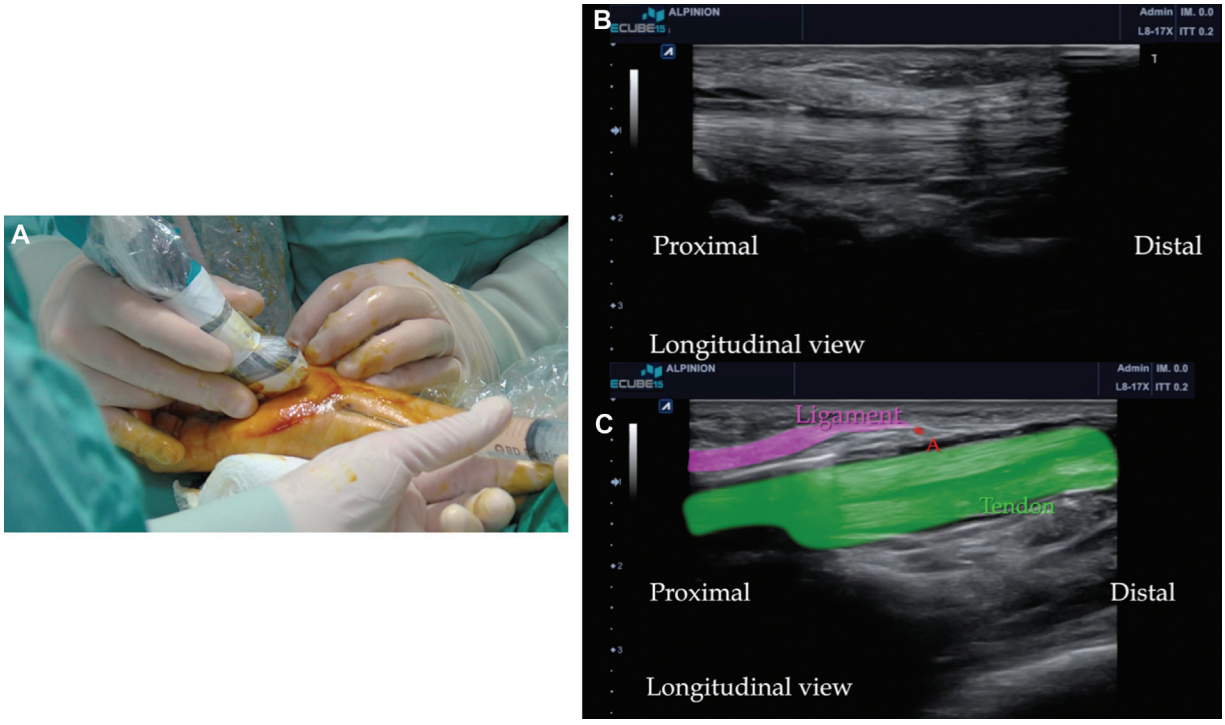

Fig. 15 (**A**, **B**, **C**) Longitudinal in-plane infiltration of CTS. Images showing the needle down the flexor retinaculum for the anesthetic procedure.

order of 1.5 cm). Percutaneous or US-guided surgeries enable an approach that is 10 times smaller, in the order of 1 mm to 2 mm.[32]

Numerous studies comparing endoscopy with "open" surgery have shown that minor incisions enable a reduction in complications and a faster recovery. Hamed compared a double incision technique (limited palmar and mini-open at the distal antebrachial crease) with the conventional open method, and showed that there was a very significant reduction in postoperative pain such as pillar pain and scar sensitivity (48% versus 14.7%, and 57.1 versus 21% respectively).[32–34]

The development of percutaneous US surgery, which involves a smaller incision, appears to enable a faster recovery, and the care after the surgery is simpler. However, comparative studies are rare, and not all teams use this technique

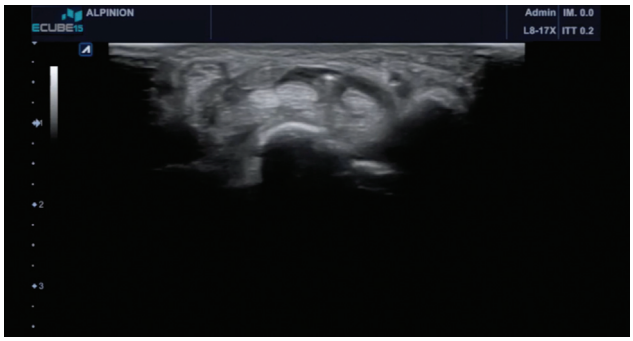

Fig. 16 Transverse view of the carpal tunnel showing the needle down the flexor retinaculum for the anesthetic procedure.

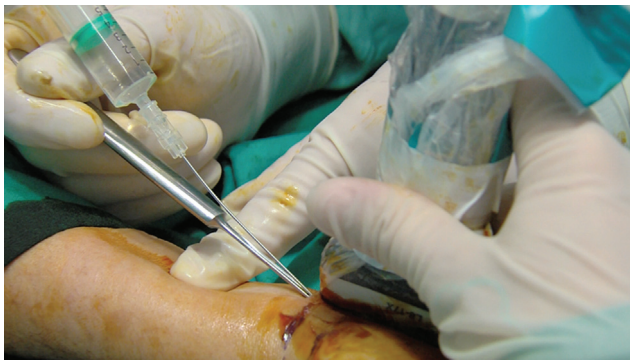

Fig. 17 Insert a V-shaped curet of two sizes into the carpal tunnel.

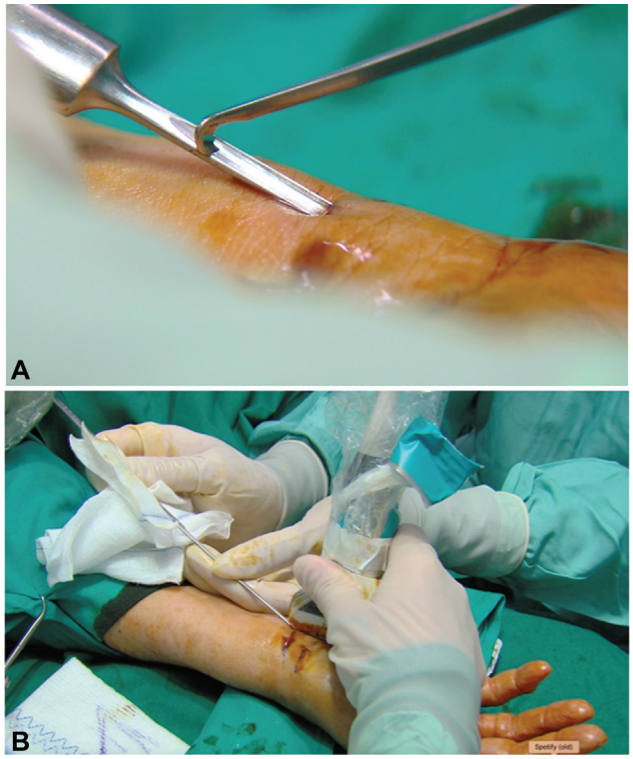

Fig. 18 Insert the Acufex 3.0-mm hook knife with a retrograde blade (010600; Smith & Nephew PLC, London, England) and advanced into the carpal tunnel.

uniformly.Mc Shane et al.[32] performed complete release of the carpal tunnel under US guidance with the bevel of a needle. This is the less invasive surgical approach described so far, as they only used the bevel of a needle, but the authors termed it percutaneous.

Capa-Grasa et al.,[35] Jugovac et al.,[36] and Rojo-Manaute et al.[37,38] performed similar procedures with the use of a hook knife. After piercing the skin and superficial fascia with a cannula (Abbocath, Abbott Laboratories Ltd., Maidenhead, United Kingdom), they inserted a retrograde hook knife with a 3 mm section to perform the section of the ligament. However, due to the elasticity of the skin, the final wound has 1 mm to 2 mm. The entire procedures were performed with US monitoring. Despite a larger incision than of the one performed by McShane et al.,[32] Rojo-Manaute et al.[37,38] were the first to use the term "ultra-minimally-invasive surgery." Capa-Grasa et al.[35] and Rojo-Manaute et al.[37,38] also compared US-guided surgery with a portal of 1 mm to mini-open surgery with a portal of 20 mm in 129 patients. The functional score (on the short version of the DASH, called QuickDASH), the grip strength, the lack of paresthesia, and the resumption of everyday activities and work were evaluated. The functional score improved significantly faster for the group that had undergone US surgery than for the one treated by mini-open surgery. It was therefore 2 times less severe after only 1 week (23.6 versus 52.6), and 3.3 times less severe 6 months after the intervention (4.9 versus 13.0). On average, the resumption of daily activities occurred significantly earlier for the group treated by US surgery (after only 4.9 days versus 25.4 days on average after mini-open surgery).[35,37,38]

Chern et al.[39,40] obtained satisfactory results in 91 patients with retrograde section of the FR involving ultrasound guidance, although this was through a superficial approach above the retinaculum.

Dupuytren Disease

Palmar fibromatosis, also known as Dupuytren disease, is a benign fibroproliferative disorder in which subcutaneous fibrous nodules arise within the palmar fascia of the hand, eventually forming cord-like attachments with the adjacent flexor tendons.[42–45] Progressive shortening of these cord-like attachments ultimately results in flexion contractures of the fingers.

Dupuytren contracture most commonly affect the fourth digit, followed by the third, fifth, second, and first digits in decreasing order of frequency. It affects 20% of people older than 65 years, and is associated with diabetes mellitus types 1 and 2, alcoholism, and epilepsy. Although an underlying genetic predisposition and a propensity of palmar fibromatosis to affect white people of Northern European descent is supported by twin and family studies, a multifactorial etiology is suggested by additional studies,[42–44] and it implicates trauma, microvascular injury, and immunologic processes.

Ultrasound may be used to confirm palmar fibromatosis and for the imaging-guided treatment.[46–48]

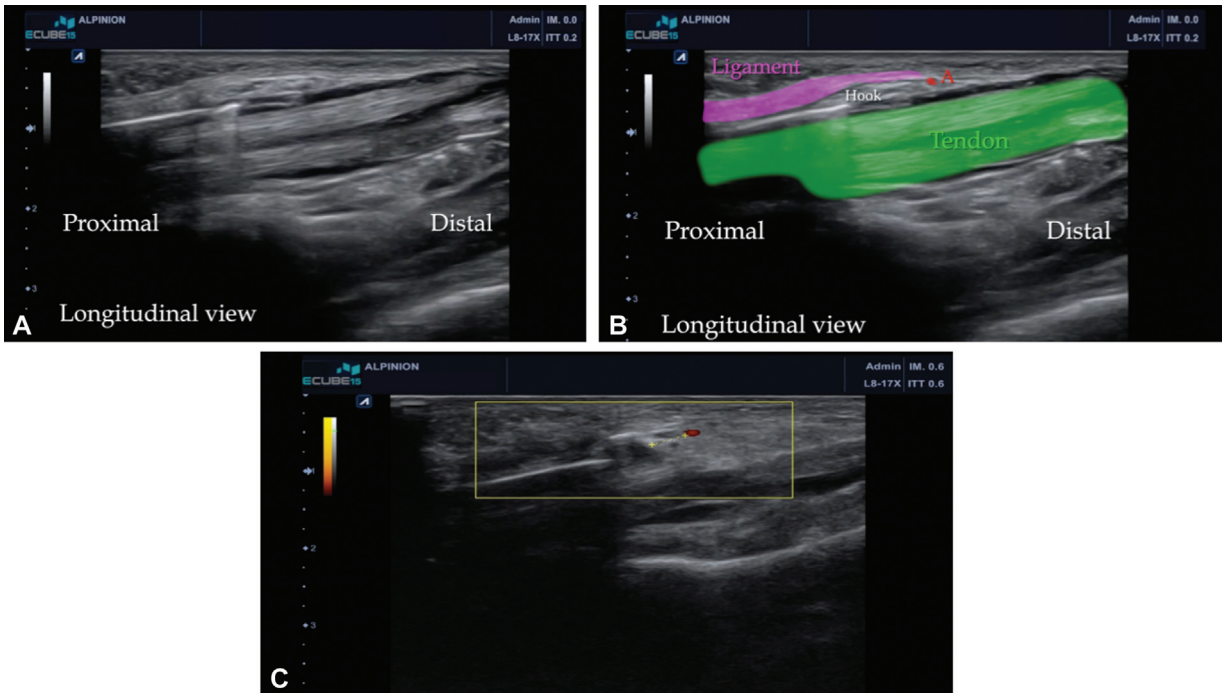

Fig. 19 (**A, B, C**) Insert the Acufex 3.0-mm hook knife with a retrograde blade. Ultrasound view on the longitudinal plane. We must advance and stop before the arterial palmar arch.

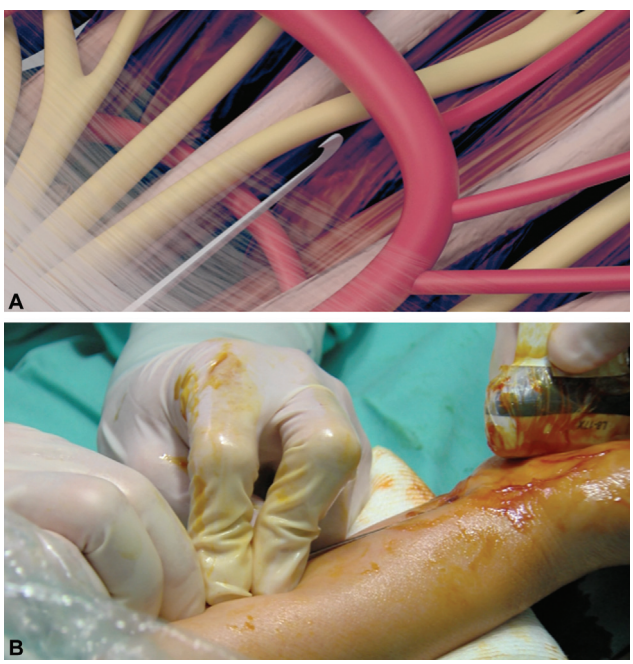

Fig. 20 (**A, B**) Turn the hook knife and pull proximally to release the flexor retinaculum retrogradely.

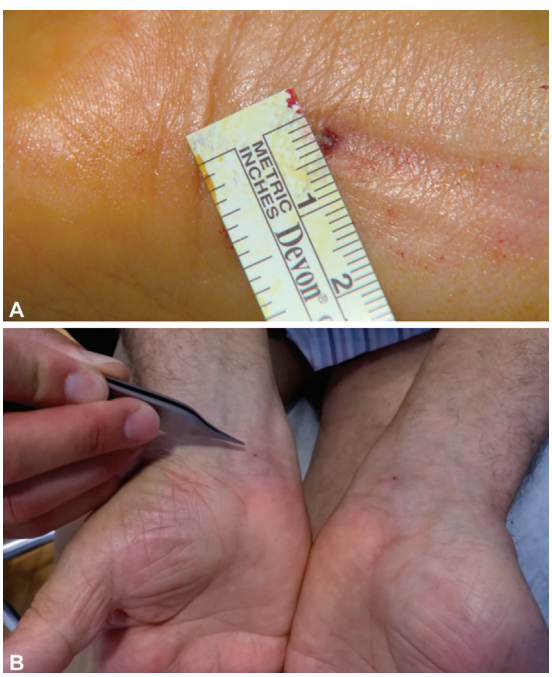

Fig. 21 (**A, B**) Size of the incision of CTS ultrasound release in a bilateral case.

Ultrasound Appearance of Dupuytren Disease

On US, the lesions are typically located directly superficial to the flexor tendons (93%), with their epicenter in the region of the distal metacarpal bone (89%). Dupuytren lesions are characteristically hypoechoic (98%) and noncompressible (95%).[46]

Sometimes we can find atypical features: intralesional calcification (2%), compressibility (5%), and hyperemia on color Doppler images (6%).[46]

We can also find lesions more distally than usual, in the region of the metacarpophalangeal joint and the proximal phalanx. Less frequently, the lesions can be located superficial but lateral to the flexor tendons, rather than directly superficial to them.[46]

Several benign and malignant lesions in the hand may simulate palmar fibromatosis: epithelioid sarcomas, giant cell tumors of the tendon sheath, ganglion cysts, inclusion cysts, stenosing tenosynovitis without

triggering, edematous changes in the hand, and thickening and callus formation related to occupational activity.[44] Familiarity with the imaging features of palmar fibromatosis can aid in distinguishing this disease from these entities.

Ultrasound guidance is used for collagenase injection therapy or surgical procedures to avoid complications in tendons and neurovascular structures.[48]

During the past ten years, the complications and long-term postoperative recovery associated with limited fasciectomy (LF) have led to the use of minimally-invasive techniques, including collagenase injections and percutaneous needle aponeurotomy (PNA).[46–53]

A systematic review of the literature[49–59] demonstrates an overall complication rate below 4% with PNA. The most common complication is skin tears, which may occur in 4% to 16% of the cases, with tendon damage or complex regional pain syndrome being exceptional. The complication rate may be lower in non-advanced forms and when the surgeons are expert in the technique.[49–59]

Most authors do not use US since the cord must be palpable as a prerequisite before blind techniques are applied. Joint contracture is considered a relative limitation for needle aponeurotomy, as it is the presence of a palpable cord.[49–51,59]

We have recently described[47,48] the technique and results of US-guided aponeurotomy (USGA) and interphalangeal capsule release in patients with Dupuytren disease. Ultrasound enables the direct visualization of the cords and control of the flexor tendons and neurovascular bundle. Even in cases with interphalangeal joint contracture, we can release the capsule while preserving these structures.

Surgical Procedure for Dupuytren Disease[47,48]

The instrument set included a series of needles (22G, 21G, 18G, and 16G), a V-shaped straight curette, a blunt dissector, and an ultrasound device with a 10- to 17-MHz linear transducer. Hockey-stick may be recommended for contractures over 80°, as normal lineal probes may be difficult to adapt. The patient is placed in the supine position with the hand resting on an arm board and facing upward. It is not necessary to apply a tourniquet. We do not use a malleable hand retractor, since we perform the procedure with two surgeons, as with our other US-guided procedures.[47,48]

The cords are palpated and then identified with the probe in both the transverse and longitudinal planes. We mark the tract of the cord and select several entry points, from proximal to distal, between the metacarpal zone and the interphalangeal zone. Skin areas without severe retraction are preferred.

The portals are chosen on the ulnar side of the ray with the probe over the cord ►**Fig. 22 (A, B, C)**.

The tendons, nerves, and vessels are always under direct control of the surgeons ►**Fig. 23 (A, B)**.

The needle and the syringe loaded with anesthetic (lidocaine 1%/adrenaline 1: 100,000) are used as a scalpel. First, we insert a little of anesthetic close to the cord in the selected portal.

With the probe in the transverse plane, we insert the needle under direct visualization from a lateral (ulnar) entry point, rather than making multiple and blind perpendicular punctures as is the case in non-US-guided aponeurotomy. We open several portals starting proximal and moving distal, toward the fingers.

The movement of the needle is monitored. The procedure can be performed with needles of different thicknesses. The needle is inserted from ulnar to radial at the point selected, with the transducer in the same plane as the needle along the

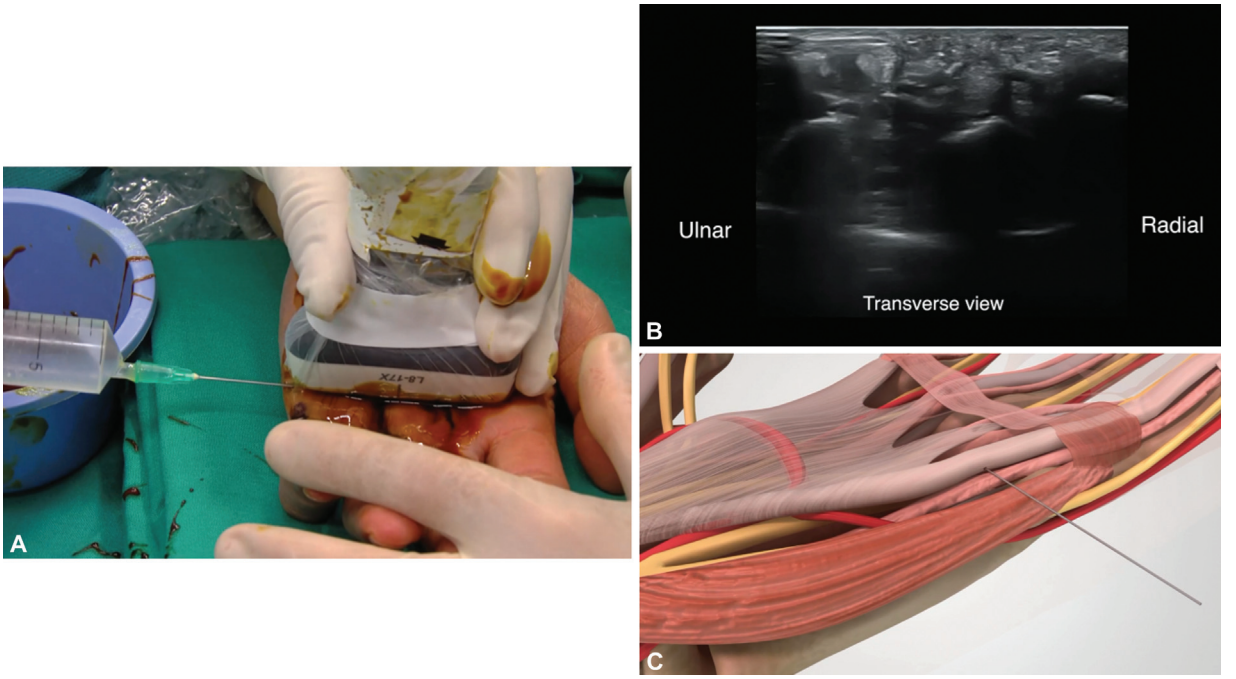

Fig. 22 (**A, B, C, D**) Ultrasound-guided aponeurotomy in Dupuytren disease. The portals are chosen on the ulnar side of the ray with the probe over the cord.

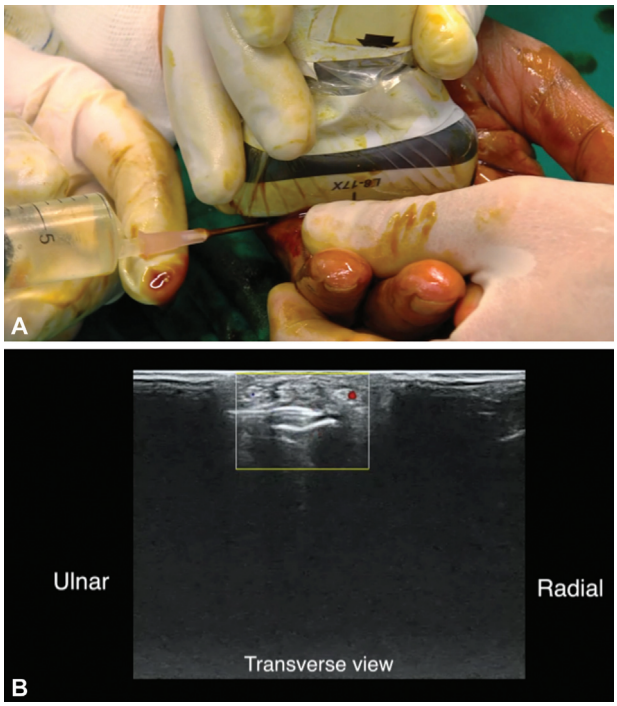

Fig. 23 (A, B) Ultrasound-guided aponeurotomy in Dupuytren disease. Release of the proximal interphalangeal (PIP) joint. Doppler showing the location of the neurovascular bundle.

Fig. 24 (A, B) Dupuytren Tubiana stage II, before and after US-guided aponeurotomy.

short axis or the axis that is transverse to the cords. Multiple perforations are made from ulnar to radial and from deep to superficial at all selected points until the cord is released.

Reducing the tension of the cords at several points minimizes skin complications when the fingers are extended. The depth of the needle and its position with respect to arteries and nerves can be controlled using US in two planes.

Skin retractions into the subcutaneous tissue are released by severing the diseased fibers that insert into the dermis by moving the needle or the curette following a horizontal windshield wiper motion in the plane just below the skin.

After a first phase of multiple horizontal perforations from ulnar to radial, we start making a levering movement from deep to superficial, and the sharp bevel of this needle cuts the cord like a knife. It is very important to maintain the position of the needle and the probe and the cord under tension in the same plane while making the perforations, because if the tension is released, the plane the needle was originally in will be lost, possibly rendering the aponeurotomy more difficult.[46]

Interphalangeal contracture is a problematic issue with blind surgery. Ultrasound-guided surgery enables the contracture to be released with direct control of the nerves and vessels, by staying immediately beneath them. For this surgical gesture, we prefer 22G and 18G needles.[46,59]

When we feel that the cord is sufficiently loose at several points, or if we can pass the needle through it, we extend the finger and break the cord. The surgeon can feel the release of the cord like a snap. We complete the proximal cuts by flexing the fingers and extending the metacarpophalangeal joint, thus reducing skin tension. We complete the distal cuts by flexing the wrist and metacarpophalangeal joint and extending the finger.[46]

We can then check the final result and ask the patient to flex and extend his/her hand.

The patient can move the hand immediately after the procedure. No sutures are required. We use adhesive strips and an elastic bandage.

We have treated almost 100 patients with excellent results, and we have already reported our results with the first 70 patients.[47]

We can operate on bilateral cases with this technique at the same time.[46] We can apply this technique, which is safe and reliable, in the operating room, and we recently started applying it in the office: ►**Fig. 24 (A, B)** and ►**Fig. 25 (A, B)**.

Results

In our recently published series,[47] the contractures were Tubiana stage I in 15 cases, stage II in 41, and stage III in 14 cases. In 21% of the cases, the digits had isolated metacarpophalangeal joint contractures. A total of 2 cases (3%) involved an isolated proximal interphalangeal joint contracture (stage II). The remainder (53 fingers, 76%) involved contractures of both the metacarpophalangeal and proximal interphalangeal joints.

Proximal interphalangeal capsule release was performed in 15 cases with digital deformity (11 cases with Tubiana stage III and 4 patients with Tubiana stage II). The preoperative mean contracture was of 70° (range: 35°–115°). The mean preoperative metacarpophalangeal joint contracture was of 39° (range: 25°–65°), and the mean preoperative proximal interphalangeal contracture was of 40° (range: 15°–70°) (excluding the 15 cases with isolated metacarpophalangeal deformity). The mean improvement after surgery

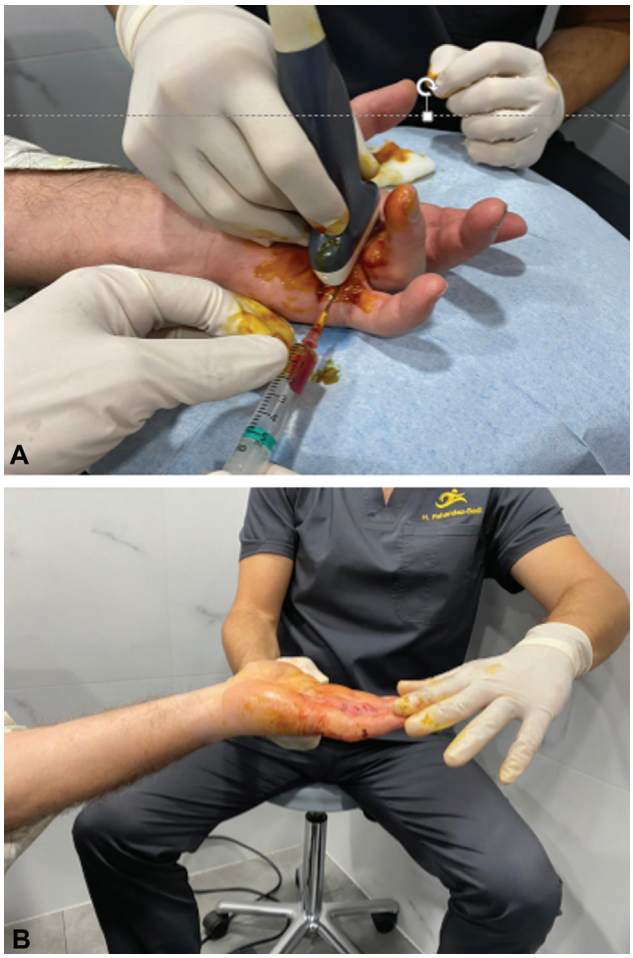

Fig. 25 (**A**, **B**) Dupuytren Tubiana stage II, before and after US-guided aponeurotomy.

was of 67°, which represents 95% of the contracture. The mean residual contracture was of 4° (range: 0°–15°). Metacarpophalangeal joint contractures were corrected in 95% (37°) on average, and the proximal interphalangeal joint contractures, 94.5% (38°) on average immediately after surgery (excluding the 15 cases with isolated metacarpophalangeal deformity).

At 1 and 2 years of follow-up, the mean correction is of 63°, which represents 90% of the initial global contracture. At 1 and 2 years of follow-up, the mean correction for the metacarpophalangeal joint contracture is of 35.3° (91.4%), and that of the proximal interphalangeal joint contracture (excluding the cases with isolated MCP deformity) is of 35°, which represents a correction of 88% of the initial contracture.

All patients were satisfied at 3 months and 1 and 2 years of follow-up, with a score of 9 on the VAS (0–10).

Conclusions

Ultrasound is a well-established imaging modality for both diagnostic and therapeutic uses in hand surgery, in the office and in the operating room.

It helps us perform guided procedures for many pathologies, such CTS, trigger finger, or Dupuytren disease. With these techniques, we minimize the morbidity in hand surgical procedures, providing early recovery to the patients.

Ultrasound-guided surgery may help reduce complications, fasten recovery and improve results. It may also become the gold-standard form of surgery for certain pathologies in the near future.

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