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Ultrasound findings in 46 cases of incomplete release of the transverse carpal ligament in carpal tunnel surgery

Ultraschallbefunde in 46 Fällen einer unvollständigen Durchtrennung des transversalen Karpalbandes bei einer Karpaltunneloperation

Authors
Marco Becciolini[1, 2], Giorgio Tamborrini[3], Christopher Pivec[4], Georg Riegler[5]

Affiliations
1 Ultrasound, Misericordia di Pistoia, Pistoia, Italy
2 Ultrasound, Scuola Siumb di Ecografia Muscolo-Scheletrica, Pisa, Italy
3 Institute of Rheumatology, Swiss Ultrasound Center, Basel, Switzerland
4 Ultrasound, PUC – Private Ultrasound Center Vienna, Vienna, Austria
5 Ultrasound, PUC – Private Ultrasound Center Graz, Graz, Austria

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Correspondence
Dr. Marco Becciolini
Ultrasound, Misericordia di Pistoia, Via Bonellina 1, 51100 Pistoia, Italy

ABSTRACT

Purpose To describe the ultrasound (US) features of a complication in patients who have undergone surgery for carpal tunnel syndrome (CTS): the incomplete release of the transverse carpal ligament (TCL).

Materials and Methods Reports from two institutions were searched using the keywords "persistent CTS" and "incomplete TCL release". Post-surgical US examinations were performed using a standardized approach at both institutions, first assessing the muscles supplied by the median nerve (MN) and then conducting a detailed evaluation of the MN course at the wrist. To avoid misinterpreting ligament regrowth, patients with recurrent symptoms two months or later after surgery were excluded. Only cases showing clear compression by the TCL were selected.

Results A total of 46 patients were identified with incomplete release of the TCL, with the average uncut portion of the ligament measuring 6.7 mm. The proximal margin of the TCL was incompletely released in 65 % of the cases, while the distal margin was affected in 35 %. Symptoms in these patients persisted after surgery, and, in 52 %, they were worse than before surgery. A reduction in thenar muscle bulk was observed in 37 patients. Follow-up clinical data were available in eight patients, with three undergoing US evaluation after revision surgery.

Conclusion US can effectively demonstrate the incomplete release of the TCL, visualized as a fibrillar uncut structure compressing the MN and producing an hourglass appearance of the nerve. In addition, US may help detect other factors that contribute to persistent symptoms and help to guide revision surgery.

ZUSAMMENFASSUNG

Ziel Beschreibung der Ultraschall (US)-Merkmale einer Komplikation nach Karpaltunnelsyndrom (KTS) Operation: die unvollständige Resektion des transversalen Karpalbandes (TCL).

Materialien und Methoden Berichte aus 2 Einrichtungen mit den Stichwörtern „persistierendes KTS" oder „unvollständige TCL-Resektion" wurden durchsucht. Die vom Nervus medianus (MN) versorgten Muskeln und der Verlauf des MN am Handgelenk wurde untersucht. Um eine Fehlinterpretation durch erneutes Bandwachstum zu vermeiden, wurden Patienten mit wiederkehrenden Symptomen 2 Monate oder später nach der Operation ausgeschlossen. Es wurden Fälle ausgewählt, die eine Kompression durch das TCL aufwiesen.

Ergebnisse Bei insgesamt 46 Patienten wurde eine unvollständige Durchtrennung des TCL festgestellt, wobei der nicht durchtrennte Teil des Bandes im Durchschnitt 6,7 mm maß. Der proximale Rand des TCL war in 65 % der Fälle unvollständig, während der distale Rand in 35 % der Fälle betroffen war. Die Symptome hielten nach der Operation an und waren in 52 % schlimmer als vor der Operation. Bei 37 Patienten wurde eine Abnahme der Thenarmuskelmasse festgestellt. Bei 8 Patienten lagen klinische Folgedaten vor, bei 3 Patienten wurde nach der Revisionsoperation eine US-Untersuchung durchgeführt.

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Schlussfolgerung Mit US kann die unvollständige Durchtrennung des TCL dargestellt werden. Das TCL erscheint als fibrilläre, nicht durchtrennte Struktur, die den MN zusammendrückt und ein sanduhrförmiges Erscheinungsbild des Nervs erzeugt. Die US-Untersuchung kann helfen, Faktoren zu erkennen, die zu anhaltenden Symptomen beitragen und eine Revisionsoperation unterstützen.

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Introduction

Carpal tunnel syndrome (CTS) is the most common entrapment neuropathy, affecting the median nerve as it passes through the carpal tunnel in the wrist [1]. CTS is characterized by numbness in the radial three-and-a-half digits of the hand, tingling, and pain. Prolonged and severe compression usually can also lead to motor deficits, reduced grip strength, and thenar eminence atrophy [2]. Surgical intervention (carpal tunnel release) involves cutting the transverse carpal ligament (TCL) to relieve pressure on the median nerve (MN). It is one of the most common hand operations performed [3]. While surgery is generally effective, symptoms may persist or recur in 3 % to 20 % of cases [1]. One of the causes of persistent disease is incomplete release of the TCL (▶ **Fig. 1**) during surgery, which can lead to persistent or even worse symptoms. This represents a significant complication with implications for patient outcomes, potentially requiring revision surgery [4].

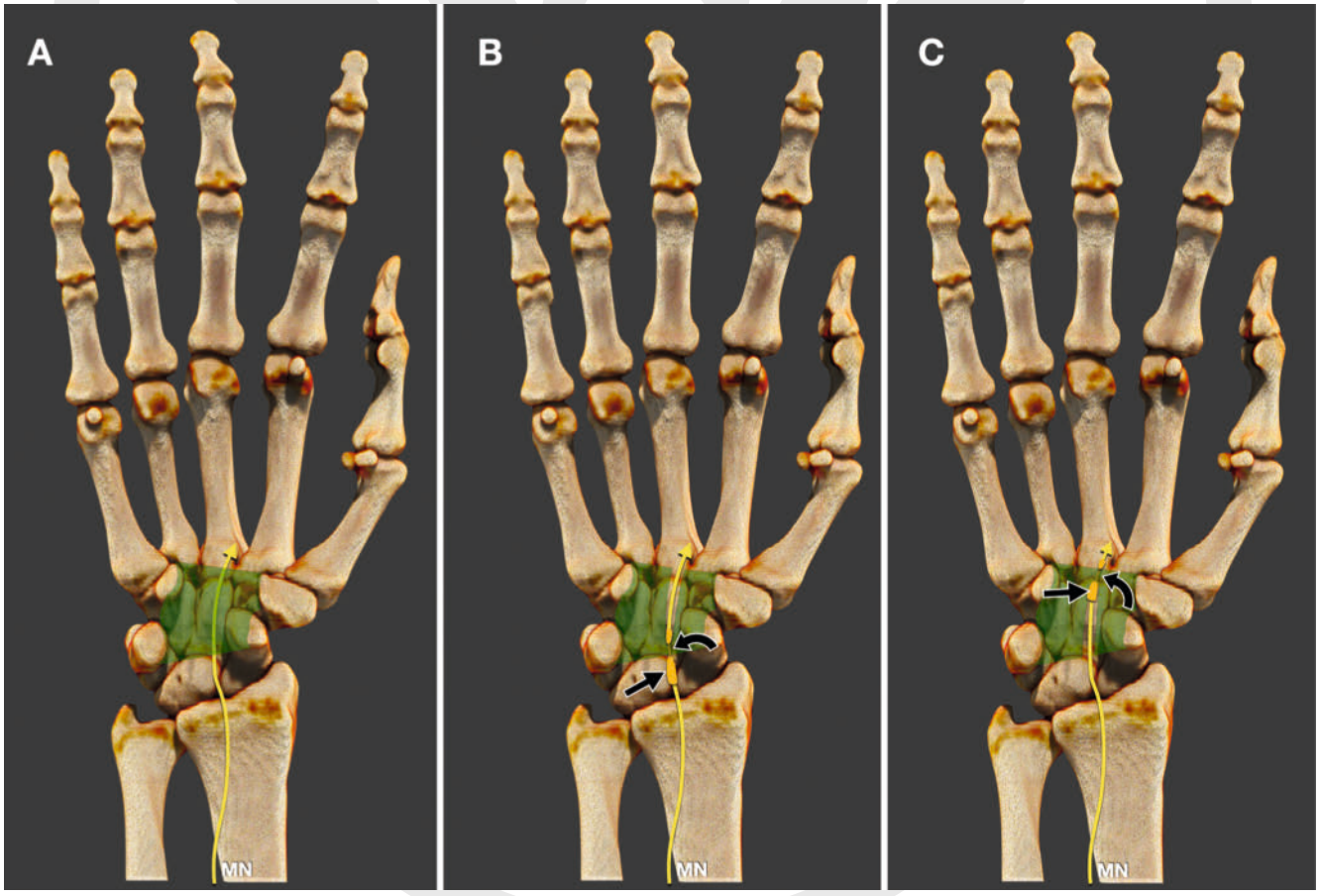
Ultrasound (US) can provide detailed imaging of the normal anatomy of peripheral nerves and, in particular, the MN at the wrist, as well as pathological changes [5, 6, 7, 8, 9, 10, 11, 12].

We present a series of 46 cases in which US revealed an incomplete release of the TCL after surgery.

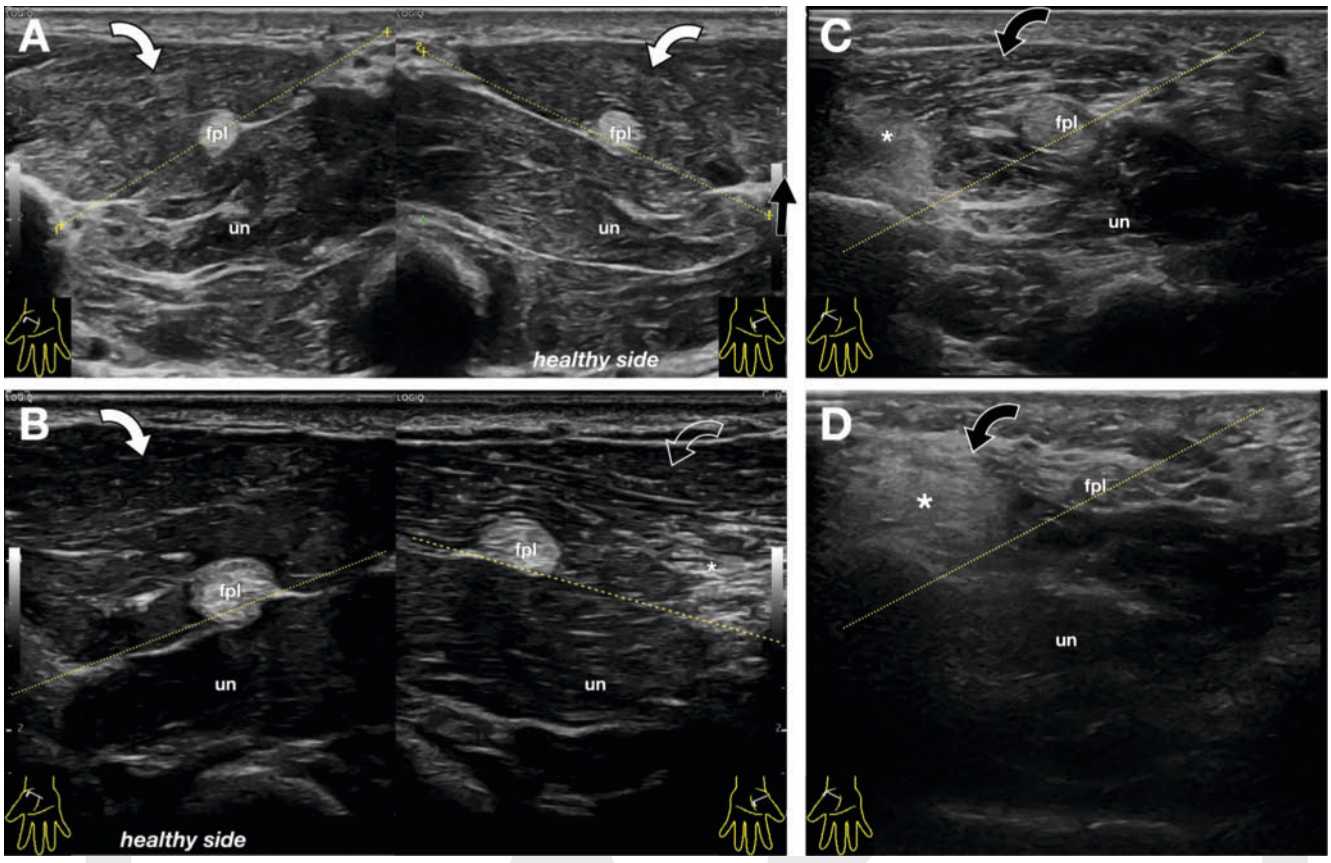
Materials and Methods

The institutional review board approved this retrospective study, and informed consent was obtained from all of the patients.

US reports from two different institutions from January 2021 to March 2025 were searched using the keywords “persistent



▶ **Fig. 1** The course of the median nerve at the wrist and incomplete section of the TCL. **A–C**: Schematic drawing of the course of the median nerve (MN) at the wrist based on a rendered 3 D CT. In **A**, the nerve normally passes deep with respect to the TCL (shaded in green). In **B**, in the proximal incomplete release, the ligament is not completely cut at its proximal margin (curved black arrow). The nerve assumes an hourglass aspect, usually being more thickened (black arrow) proximal to the uncut TCL. In **C**, similar nerve findings are present in the distal incomplete TCL release.



▶ **Fig. 2** Intrinsic muscles of the hand supplied by the median nerve – muscle bulk grading. **A–D**: Axial-oblique sonograms obtained from different patients at the level of the thenar eminence. The flexor pollicis longus (FPL) is depicted in its short axis and serves as a reference, with an imaginary oblique line (dashed yellow lines) dividing the muscles supplied by the ulnar nerve (un), located deep and ulnar; from those supplied by the median nerve (indicated by the curved arrow), located superficial and radial. **A**: Patient 13 – A comparative image in which the thenar muscles of the affected right side appear almost similar to those on the healthy side (both indicated by the curved white arrow). This was graded as "Preserved". **B**: Patient 6 – A comparative image demonstrates a mild reduction in the muscle bulk of the left hand (shown on the right, indicated by the open curved arrow), with mild hyperechoic areas (small asterisk), better depicted with a very high-frequency transducer (hockey stick 6–24 MHz). This was graded as "Mild Reduction". **C**: Patient 11 – Hyperechoic areas (asterisk) within the muscles supplied by the median nerve (black curved arrow) are more diffuse and clearly visible, even without the need for comparison. This was graded as "Moderate Reduction". **D**: Patient 9 – The muscles supplied by the median nerve (black curved arrow) appear almost "white", indicating fatty infiltration (large asterisk). This was graded as "Severe Reduction".

CTS" or "incomplete TCL release". Static images and video clips were retrieved from the PACS system and were reviewed along with the examination reports. Only cases showing clear compression by the TCL were selected. Patients in whom symptoms developed two months after surgery or later were excluded.

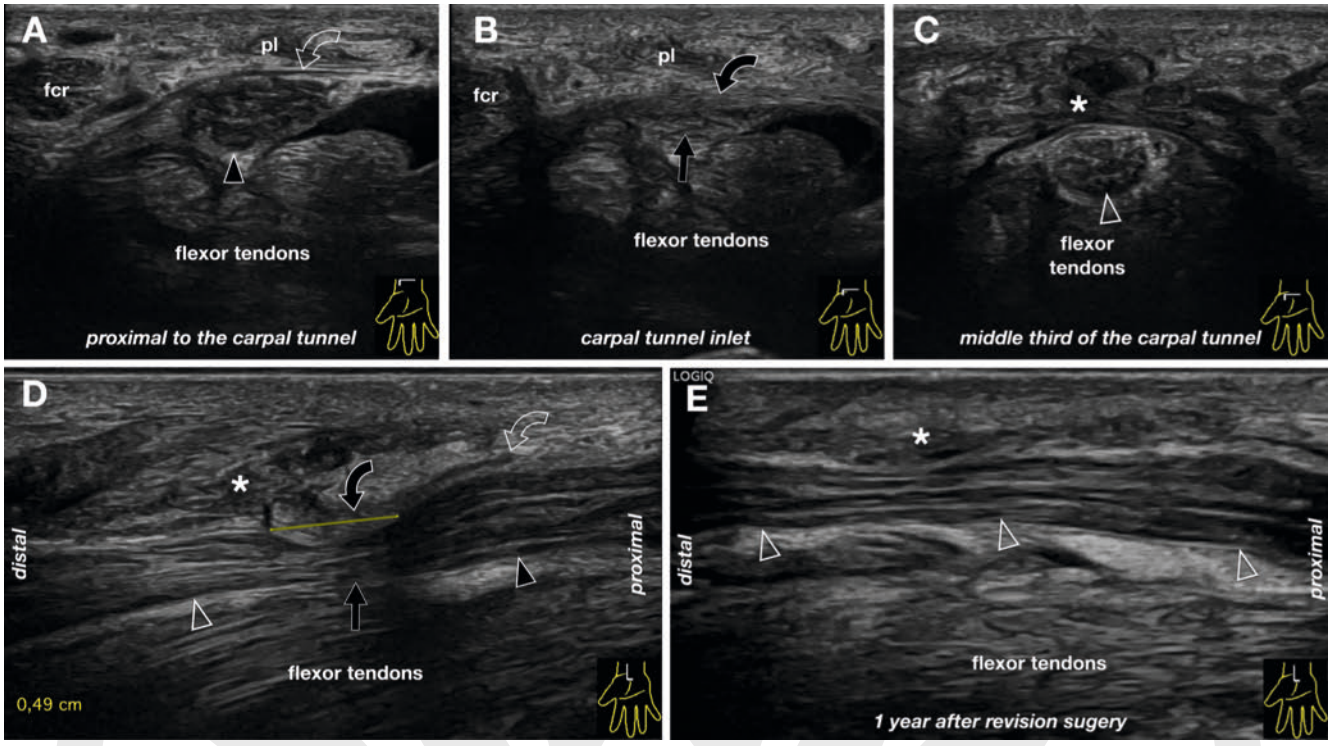
Two clinicians (MB, GR), each with more than 10 years of musculoskeletal and nerve US experience, performed the US examinations. The following US machines were used: a LOGIQ E10 with a 15–6 MHz linear transducer and a 24–6 MHz hockey stick probe at the first site and a LOGIQ S8 with a 15–6 MHz linear transducer and an 18–8 MHz hockey stick probe at the second.

Before the US examinations, the request and previous medical reports were reviewed, and a brief clinical history and basic physical examination were obtained. Patients without symptoms typical of persistent CTS were excluded. We asked the patient to define whether CTS symptoms (e. g., dysesthesia of the radial three-and-a-half fingers) were similar or increased with respect to before surgery.

The US examination protocols for failed surgery were similar across both institutions. First, using a standardized approach, images of the intrinsic muscles of the hand supplied by the MN were acquired and compared with the contralateral side to assess potential muscle belly reduction [6, 13, 14]. For this retrospective study, we subjectively graded the muscles as preserved (looking normal) or reduced (mild, moderate, and severe) (▶ **Fig. 2**).

Next, a meticulous scanning technique was adopted to examine the carpal tunnel region and identify potential causes of surgical failure. Transverse sonograms were used to track the MN in its short axis, starting at the distal forearm (▶ **Fig. 3A**), followed by longitudinal sonograms where pathology was suspected or identified. Nerve alterations, abrupt changes in its caliper, and signs of MN iatrogenic injuries were recorded. If an abrupt change in nerve caliper was detected, care was taken to determine whether the nerve was compressed by a fibrillar structure visible in the axial planes (▶ **Fig. 3B**), which would be consistent with an uncut portion of the TCL. The carpal tunnel was also evaluated distally to confirm the cut ligament (▶ **Fig. 3C**). The uncut TCL was then con-

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▶ **Fig. 3** Patient 2. Incomplete proximal release of the TCL. **A–C**: Axial B-mode sonograms obtained with a 24 MHz hockey-stick transducer, near the carpal tunnel, from proximal (**A**) to distal (**C**), one month after surgery for carpal tunnel, in a patient with paradoxical worsening of symptoms. In **A**, the median nerve (black arrowhead) appears quite swollen, under a normal-looking antebrachial fascia (curved open arrow). In **B**, the nerve is markedly flattened (black arrow) under a fibrillar structure (curved black arrow), consistent with the uncut TCL. In **C**, note the paraphysiological change of the TCL related to surgery (asterisk). The MN shows a more preserved appearance. **D–E**: Long-axis sonograms of the nerve at the level of the carpal tunnel. D was obtained at the same time as the previous axial sonograms, whereas E is a corresponding image obtained one year later, after revision surgery. Note in D the fibrillar uncut TCL (curved black arrow, measuring around 5 mm) compresses the nerve, giving an hourglass appearance, that is resolved in E, one year after revision surgery, so that the median nerve (open arrowheads) has an almost normal appearance, with some paraphysiological scarring (asterisk) superficial to the nerve. Fcr, indicates the flexor carpi radialis; pl, palmaris longus.

firmed in the longitudinal plane (sagittal sonograms) and measured along the long axis of the MN to define its craniocaudal extension (▶ **Fig. 3D**), with measurements rounded to the nearest millimeter (e. g., 4.9 mm was reported as 5 mm).

Additional findings potentially related to persistent symptoms, such as flexor tenosynovitis or osteoarthritis, were also reported.

Each author reviewed the images, and only cases consistent with incomplete release of the TCL were included. Other causes of surgical failure, such as iatrogenic MN damage, were excluded.

Follow-up data were available for some patients, including clinical data by the referring hand surgeon or US examinations if the patient returned for further imaging (▶ **Fig. 3E**; ▶ **Fig. 4A–B**).

Results

We identified 46 patients with incomplete release of the TCL.

The data are summarized in ▶ **Table 1**. Thirty (65 %) patients had a proximal incomplete release (▶ **Fig. 2**), while sixteen (35 %) had a distal one (▶ **Fig. 5**). The median age was 68 years (range: 33–95 years). Patients presented for a US evaluation at a median time of seven months after surgery (range: 1–35 months). The average length of the uncut TCL was 6.7 mm (range: 4–16 mm).

In the majority of the patients (43), symptoms were present almost immediately after surgery, while symptoms developed one month later in three patients.

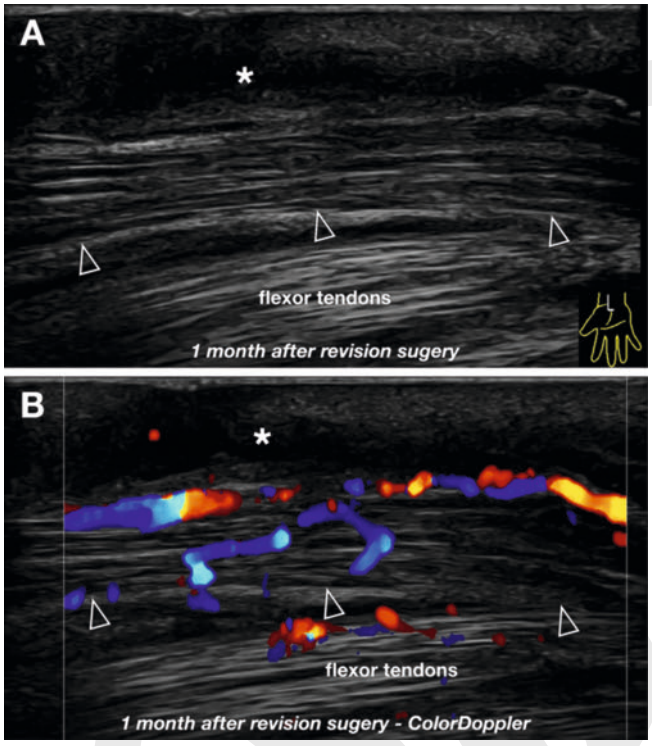
In 24/46 cases (52 %), symptoms were even worse than before surgery.

Thenar muscles supplied by the median nerve showed a muscle bulk reduction in 37 patients, which was mild in 10, moderate in 15, and severe in 12.

Seven patients presented with signs of osteoarthritis (involving the radio-carpal, the mid-carpal, the trapeziometacarpal, or the scaphotrapeziotrapezoid joint); five wrists showed diffuse calcifications of the triangular fibrocartilage complex and of the volar wrist capsule, suggestive of chondrocalcinosis, and flexor tenosynovitis was present in eight patients (▶ **Fig. 6**). Other adjunctive findings are reported in ▶ **Table 1**.

Follow-up clinical data were available in eight patients: in three cases US was requested by the hand surgeon after revision surgery (▶ **Fig. 3**, ▶ **Fig. 4**, ▶ **Fig. 7**, ▶ **Table 1**), due to suboptimal outcome, to provide reassurance that the TCL had been properly cut and there were no complications. The further US assessment of patient 2 (▶ **Fig. 4E**) at one year was not clinically necessary and was not performed because the patient presented for another US examination (DeQuervain's disease of the contralateral wrist).

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▶ **Fig. 4** Patient 2. Incomplete proximal release of the TCL. Follow-up one month after revision surgery. **A–B**: B-mode (**A**) and color Doppler (**B**) sagittal sonograms at the level of the volar aspect of the wrist, one month after revision surgery. The sonogram matches the one in ▶ **Fig. 2D**. The median nerve is indicated by the open arrowheads. Note that after revision surgery, the hourglass nerve appearance is resolved. However, the patient reported pain at the level of the surgical access and diminished but persisting paresthesia. The initial suboptimal outcome of revision surgery was interpreted as related to inflammatory changes of the perinervous tissue (asterisk), as well as diffuse hyperemia as shown in B. Symptoms gradually improved.

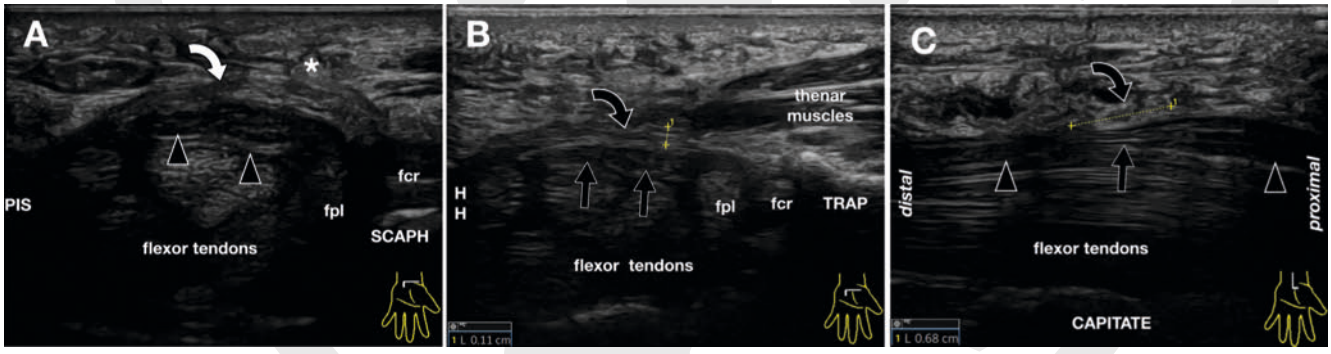
Discussion

Our cases represent the largest reported series of patients with incomplete release of the TCL in carpal tunnel surgery demonstrated on US. The uncut portions, with an average length of 6.7 mm, were located at the proximal (65 % of the cases) or distal edge (35 %) of the TCL; no patient in our series had an uncut portion at the middle third of the carpal tunnel. A potential limitation of US is the ability to clearly distinguish whether the structure that compresses the median nerve is the uncut TCL or its fascial continuation (e. g., the edge of the antebrachial fascia proximally and the palmar fascia distally). However, regardless of whether the nerve entrapment is due to uncut TCL or the edge of the fascia, US effectively depicts the persistent MN compression.

Karabay reported the US findings in 34 patients with refractory symptoms after surgery, identifying an incomplete ligament transection in eight cases [4]. Tan described the US findings in four patients, using a 10 MHz transducer, noting “indentations” of the nerve at the level where the TCL or the edge of the contiguous antebrachial fascia had not been released [15]. Our study aimed to define the US features of this surgical failure using high-frequency modern transducers. We found that an incomplete release can be identified by the presence of a fibrillar structure resembling the normal TCL, and still compressing the MN, that demonstrates an hourglass appearance in the long axis of the nerve, which becomes more evident when using a transducer with a frequency of at least 18 MHz.

Similar to our definition, Bianchi described an incomplete release as a persistent portion of the TCL associated with focal thinning of the MN [16].

Chiavaras et al. noted that distinguishing between a successful retinaculum release, an incomplete release, and scar tissue may be challenging. They observed that, after surgery, the retinaculum may appear hypoechoic and thickened, possibly with anterior displacement. However, our definition of an incomplete release



▶ **Fig. 5** Patient 10. Incomplete distal release of the TCL. **A–B**: Axial sonograms at the proximal (A) and distal (B) carpal tunnel in a patient who underwent carpal tunnel surgery two years before and reported similar symptoms around one month after surgery. In **A**, the median nerve has a bifid appearance with two contiguous bundles (black arrowheads). Years after surgery, on the radial side of the proximal TCL (curved white arrowhead), scarring (asterisk) with posterior acoustic shadowing is noted without signs of compression. Distally (**B**), a fibrillar TCL (curved black arrow, measuring around 1 mm) is depicted, bridging between the trapezius (TRAP) and the hook of the hamatum (HH), with the nerve flattened at this level (black arrow). **C**: Sagittal sonogram confirms the hourglass appearance of the nerve. The fibrillar structure consistent with the uncut TCL measured around 7 mm. Fcr indicates the flexor carpi radialis; fpl, flexor pollicis longus; LUN, lunate; PIS, pisiform.

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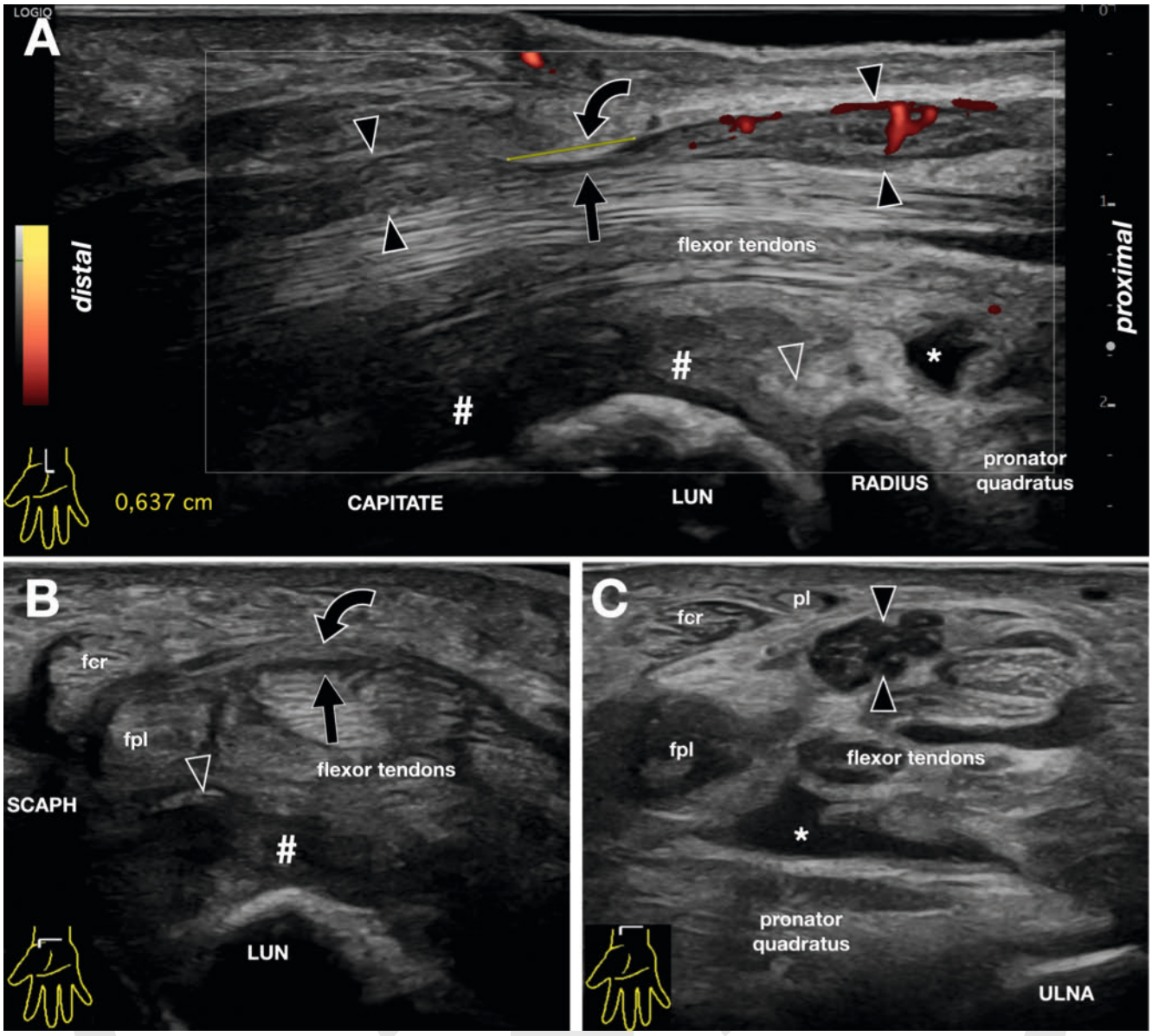
▶ **Table 1** Demographic characteristics of the patients. CKD indicates chronic kidney disease; CPP: calcium pyrophosphate deposits; FCR: flexor carpi radialis; OA: osteoarthritis; pcbMN: palmar cutaneous branch of the MN; STT: scaphotrapeziotrapezoid joint.

pt no.	Age	Time of US exam after surgery	Symptoms started (after surgery)	Symptoms intensity	Residual TCL	Residual TCL length	Thenar muscle supplied by the MN	Other findings	2nd surgery if known	US follow-up post rev. surg	1st surgery technique
1	80	9 months	almost immediately	similar	Proximal	5 mm	severe ↓	CPP; wrist OA	NO DATA		open
2	60	1 month	almost immediately	increased	Proximal	5 mm	preserved	rhizarthrosis	Yes. 1st month pain, gradual improvement in 3 months.	1 month – 1 year	open
3	63	3 years	almost immediately	similar	Proximal	7 mm	moderate ↓	volar ganglion	yes-mild improvement		open
4	50	2 months	almost immediately	similar	Proximal	5 mm	mild ↓	flexor tenosynovitis	NO DATA		open
5	85	7 months	almost immediately	increased	Proximal	4 mm	severe ↓	wrist OA	Yes. Mild improvement		open
6	58	1 year	1 month	similar	Distal	7 mm	mild ↓	UN compression Guyon zone 2	NO DATA		open
7	71	5 months	almost immediately	increased	Proximal	7 mm	moderate ↓	wrist OA	Yes. Mild improvement	6 months	open
8	80	6 months	almost immediately	similar	Proximal	5 mm	severe ↓	CPP wrist in CKD	NO DATA		open
9	84	6 months	almost immediately	similar	Proximal	6 mm	severe ↓	CPP; wrist OA	Not performed		open
10	51	2 years	1 month	similar	Distal	7 mm	preserved	bifid MN	NO DATA		open
11	59	6 months	almost immediately	similar	Distal	8 mm	moderate ↓		NO DATA		open
12	74	1 month	almost immediately	increased	Proximal	4 mm	severe ↓	rhizarthrosis, STT OA, FCR tendinopathy	Yes. Minimal improvement at 2 months	2 months	endoscopic
13	58	2 months	almost immediately	increased	Distal	6 mm	preserved		NO DATA		open
14	65	4 months	almost immediately	increased	Proximal	16 mm	moderate ↓	rhizarthrosis, STT OA	Yes. Significant improvement		open
15	71	6 months	almost immediately	increased	Proximal	6 mm	moderate ↓	Flexor tenosynovitis, CPP	NO DATA		open
16	71	9 months	almost immediately	similar	Proximal	5 mm	severe ↓		NO DATA		open
17	60	5 months	almost immediately	similar	Distal	4 mm	preserved		NO DATA		open
18	82	17 months	almost immediately	increased	Distal	8 mm	severe ↓		NO DATA		open
19	46	3 months	almost immediately	similar	Proximal	8 mm	preserved		NO DATA		open
20	58	6 months	almost immediately	increased	Proximal	6 mm	preserved		NO DATA		open
21	80	6 months	almost immediately	increased	Proximal	6 mm	moderate ↓		NO DATA		open
22	76	12 months	almost immediately	increased	proximal	5 mm	preserved		NO DATA		open
23	81	12 months	almost immediately	increased	Proximal	7 mm	severe ↓		NO DATA		open
24	70	3 months	almost immediately	similar	Distal	8 mm	severe ↓	flexor tenosynovitis	NO DATA		open

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▶ **Table 1** (Continuation)

pt no.	Age	Time of US exam after surgery	Symptoms started (after surgery)	Symptoms intensity	Residual TCL	Residual TCL length	Thenar muscle supplied by the MN	Other findings	2nd surgery if known	US follow-up post rev. surg	1st surgery technique
25	59	7 months	almost immediately	similar	Distal	4 mm	moderate ↓		NO DATA		open
26	45	5 months	almost immediately	similar	Proximal	6 mm	mild ↓	flexor tenosynovitis	NO DATA		open
27	74	4 months	almost immediately	similar	Proximal	4 mm	mild ↓	trigger finger	Yes. Significant improvement		open
28	74	11 months	1 month	similar	Proximal	4 mm	moderate ↓		NO DATA		open
29	55	3 months	almost immediately	similar	Distal	7 mm	mild ↓		NO DATA		open
30	82	1 month	almost immediately	increased	Distal	7 mm	moderate ↓	flexor tenosynovitis, neuroma pcbMN	NO DATA		open
31	56	4 months	almost immediately	increased	Distal	8 mm	mild ↓		NO DATA		open
32	77	2 months	almost immediately	increased	Proximal	5 mm	moderate ↓		NO DATA		open
33	87	3 months	almost immediately	increased	Proximal	10 mm	moderate ↓	bifid MN	NO DATA		open
34	56	7 months	almost immediately	similar	Proximal	7 mm	moderate ↓		NO DATA		open
35	65	12 months	almost immediately	increased	Distal	7 mm	preserved		NO DATA		open
36	71	1 month	almost immediately	increased	Distal	7 mm	moderate ↓	flexor tenosynovitis	NO DATA		open
37	89	10 months	almost immediately	increased	Proximal	7 mm	severe ↓	flexor tenosynovitis	NO DATA		open
38	57	12 months	almost immediately	similar	Distal	11 mm	moderate ↓	trigger finger	NO DATA		open
39	79	4 months	almost immediately	increased	Proximal	7 mm	mild ↓		NO DATA		open
40	80	3 months	almost immediately	increased	Proximal	10 mm	severe ↓		NO DATA		open
41	66	10 months	almost immediately	similar	Distal	10 mm	mild ↓		NO DATA		open
42	33	3 months	almost immediately	increased	Proximal	6 mm	preserved		NO DATA		open
43	67	3 months	almost immediately	similar	Proximal	8 mm	mild ↓		NO DATA		open
44	85	6 months	almost immediately	increased	Proximal	5 mm	moderate ↓		NO DATA		open
45	95	3 months	almost immediately	increased	Distal	8 mm	severe ↓		NO DATA		open
46	63	14 months	almost immediately	similar	Proximal	7 mm	mild ↓	flexor tenosynovitis	NO DATA		open



▶ **Fig. 6** Patient 15. Incomplete proximal release of the TCL. Associated findings. **A**: Sagittal power Doppler sonogram at the carpal tunnel in a patient with worsening symptoms after surgery (performed 6 months before). The uncut TCL (curved black arrow) is measured (around 6 mm), compressing the MN (black arrow). Proximally and distally, the nerve appears thickened (black arrowheads). Note the concomitant presence of flexor tendons tenosynovitis (asterisk) and volar radiocarpal and midcarpal capsule thickening (#), with hyperechoic foci (open arrowhead), that were present also at the triangular fibrocartilage complex (not shown), consistent with chondrocalcinosis. Nerve hyperemia was depicted proximal to the constriction point. **B–C**: Axial distal (**B**) and proximal (**C**) sonograms demonstrate in B the fibrillar uncut TCL as well as thickening of the wrist volar capsule and calcific deposits, and in C the thickened MN and the flexor tenosynovitis. Fcr indicates the flexor carpi radialis; fpl, flexor pollicis longus; LUN, lunate; pl, palmaris longus, SCAPH, scaphoid.

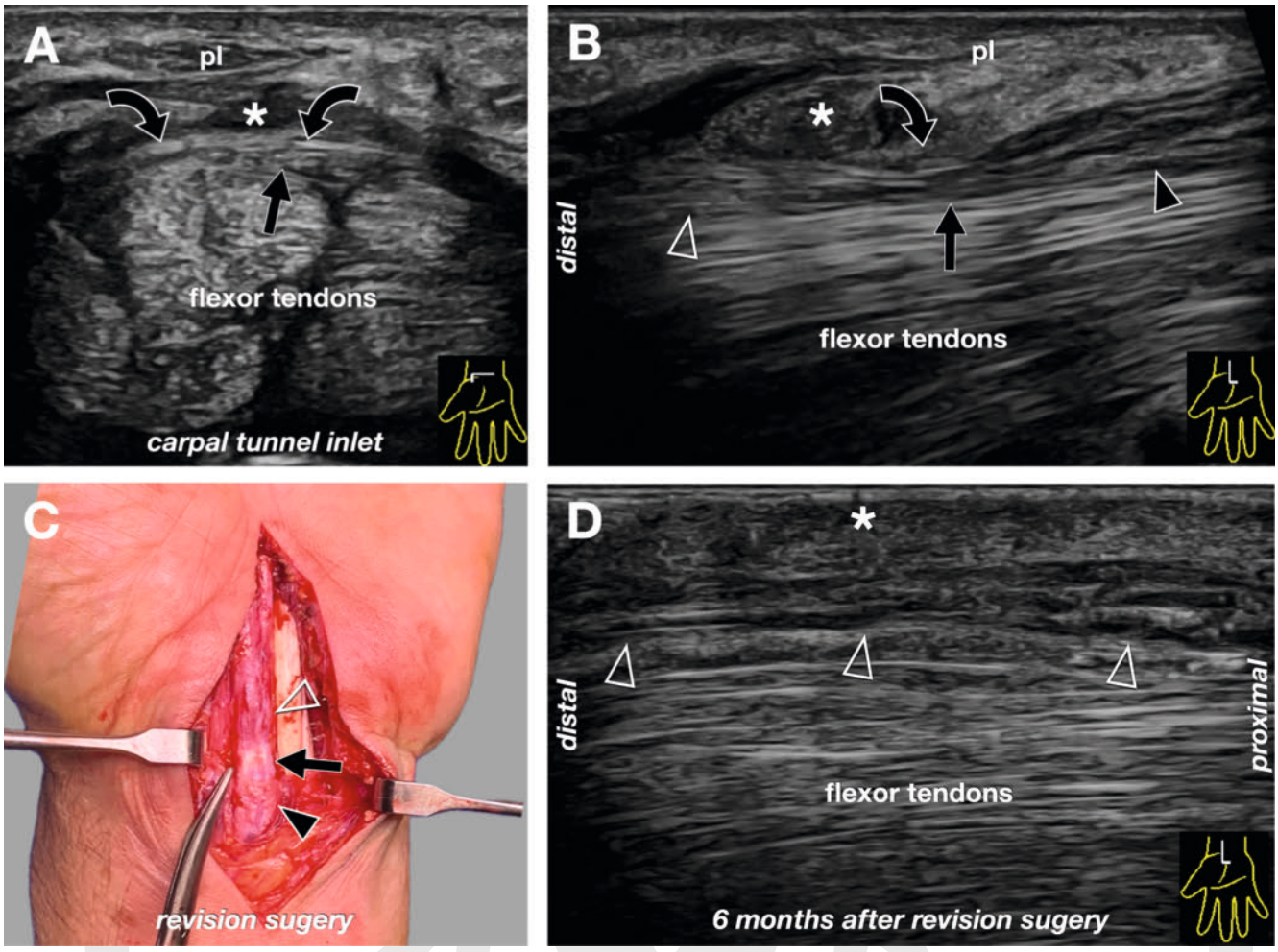
differs: it is a fibrillar and normal-appearing TCL, at the proximal or distal edge of the retinaculum itself, adjacent to a cut TCL. In the first months after surgery, the cut TCL typically appears more hypoechoic, not fibrillar, and thickened. Importantly, in the absence of excessive scarring, the cut TCL does not compress the nerve [17].

Another potential post-surgery complication that may mimic an uncut TCL on imaging is the healing of the ligament [18]. To avoid misinterpreting a healed TCL or ligament "regrowth" as defined by Campagna [18], we excluded patients who developed symptoms two months after surgery or later.

In fact, according to Forman, patients with persistent CTS never experience symptom relief, whereas recurrence may appear as early as two months post-operation [19]. Furthermore, they found that, in cases of an incompletely transected TCL, intact transversely oriented fibers without evidence of prior disruption were present, consistent with our US definition of a persistent uncut part of a normal-looking fibrillar TCL, in contrast to scarring of the TCL, where the scar tissue disrupts the transverse TCL fibers.

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▶ **Fig. 7** Patient 7. Incomplete proximal release. Intraoperative findings and US follow-up. **A–B**: Axial (**A**) and sagittal (**B**) sonograms at the level of the carpal tunnel, in a patient who underwent surgery five months before and almost immediately experienced increased symptoms. In A, a fibrillar structure (curved black arrow) compresses the nerve (black arrowhead); it is confirmed in B, giving the hourglass appearance to the nerve, which appears thickened proximally (black arrowhead) and a bit more preserved distally (open arrowhead). The asterisk indicates soft tissue changes related to surgery. **C**: Revision surgery was performed soon after. The surgical photo matches the US findings with a "hypoperfused" area of the median nerve (black arrow) where it was compressed. The black and open arrowheads indicate, respectively, the proximal and distal parts of the nerve, as shown in B. **D**: Sagittal sonogram six months after revision surgery. Although the nerve no longer showed an hourglass area of compression, symptoms were only mildly improved.

Tulipan demonstrated in ten cadaveric arms that US is a highly accurate tool with which to detect incomplete release of the TCL. However, their study did not evaluate actual patients with this complication [20].

The small subset of patients with clinical follow-up may provide insight into possible outcomes for those who undergo revision surgery after incomplete TCL release.

Suboptimal outcomes may have different causes. In particular, revision surgery performed too soon after the initial procedure may yield unsatisfactory results in the first months due to inflammatory changes in the soft tissues. This was observed in patient 2 (▶ **Fig. 4**), whose symptoms gradually improved over time (▶ **Fig. 3E**).

In contrast, symptoms may not fully resolve, as seen in patient 7, possibly due to chronic and prolonged compression. On follow-up US, the hourglass nerve compression was no longer evident (▶ **Fig. 7**), consistent with resolution of the compression on imaging. However, it is well known that patients with severe, long-standing CTS have worse prognoses after surgery [21].

Moreover, US was also helpful in avoiding revision surgery in cases such as patient 9, who had persistent similar symptoms post-surgery and a high risk of failure. This 84-year-old patient had wrist osteoarthritis (radio-carpal and mid-carpal), diffuse calcium pyrophosphate deposits of the volar wrist capsule, and severe thenar muscle atrophy, indicating chronic compression. US performed six months after surgery provided information for surgical decision-making.

Despite these insights, the small number of patients with follow-up data is a limitation of our study.

Further research is needed to better define the outcomes of revision surgery.

US-guided carpal tunnel release has recently been proposed as an alternative to open or endoscopic surgery to reduce surgical trauma [22, 23, 24, 25]. Although our retrospective study does not provide data, we may hypothesize that a selective minimally invasive US-guided release of an uncut TCL could reduce the inflammatory reaction compared to a second open revision surgery.

Another limitation of our study is that we lack data on the prevalence of the occurrence of incomplete release of the TCL.

We did not measure the maximal cross-sectional area (CSA) since the nerve compression appeared clear in both the short and long axis of the MN. Since the US and clinical picture appeared typical, we believe that, for patients with incomplete release of the TCL, CSA would add no other information.

In conclusion, incomplete TCL release leads to persistent or worsening symptoms. Our findings suggest that US is a precise tool with which to detect this surgical failure and differentiate it from other complications. In addition, US can identify other pathologies at the carpal tunnel level, providing valuable information to hand surgeons when considering revision surgery.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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