



# Ultrasound-guided percutaneous release of the carpal tunnel: comparison of the learning curves of a senior versus a junior operator. A cadaveric study

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## Abstract

**Objective** The purpose was to evaluate, in a cadaveric cohort, the feasibility and the learning curve of ultrasound-guided percutaneous carpal tunnel release.

**Materials and methods** Fourteen carpal tunnel releases were carried out on unembalmed cadavers by a senior and a junior radiologist. Procedures were realized with an 18-MHz linear probe. An anatomical evaluation was first performed using ultrasound to detect any anatomical variant. After hydrodissection of the carpal tunnel with lidocaine, a 3-mm hook knife was introduced into the security zone to perform a retrograde section of the transverse carpal ligament (TCL) under ultrasound guidance. Anatomical dissection was performed for each wrist. The main evaluation criterion was the complete TCL section. The procedure duration (minutes), skin incision size (millimeters), the integrity of the median nerve, thenar motor branch, and palmar vascular arch were also evaluated.

**Results** The senior operator was able to perform a complete release after training on three specimens and the junior operator after four specimens ( $p > 0.05$ ). In most of the cases when complete release was not achieved, it was due to an incomplete section of the distal TCL (10 mm missing section on average). Mean duration time of procedure was 14 min (11 min for the senior versus 17 min for the junior,  $p > 0.05$ ). Damage of neither the median nerve nor the vascular structure was observed. Mean size of the skin incision was 3 mm.

**Conclusion** The ultrasound-guided percutaneous release of the carpal tunnel is demonstrated to be a procedure with a rapid learning curve.

**Keywords** Ultrasound · Median nerve · Learning curve · Carpal tunnel syndrome · Cadaver

## Introduction

Carpal tunnel syndrome is a commonly diagnosed condition of the upper extremities. Surgical decompression release is the

recommended treatment when medical management is insufficient [1]. During the last 30 years, surgical techniques have become less and less invasive, with a variety of strategies. For example, the development of endoscopic treatment and “mini-

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open” mini-invasive techniques. The hypothesis is that with procedures being less invasive, it will lead to fewer post-operative complications, such as hypertrophic scarring, pillar pain, and prolonged convalescence. The endoscopic release was a promising technique but challenging: indeed, initial placement of the trocar is a blinded procedure and carries the risk of damaging anatomical structures [2].

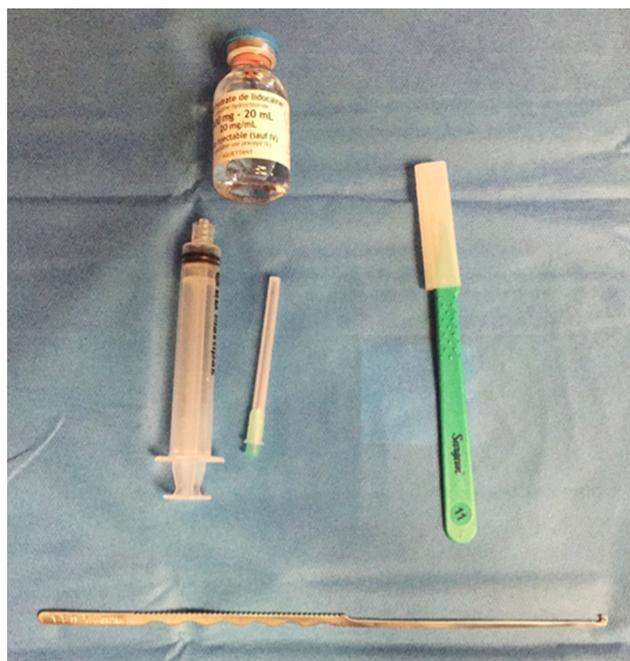
Advances in ultrasound provide a high spatial resolution, improving visualization of anatomical structures, and anatomical variants, that are important in the management of carpal tunnel release [3]. The ultrasound-guided percutaneous release of carpal tunnel is a new mini-invasive technique that has been developed for the past 20 years and necessitates a small skin incision (2 mm on average). It is a promising technique, for which efficiency and safety have been demonstrated in several studies [4–7]. However, in most of these studies, the experience and specialization of the operator are unclear. We believe that in the field of interventional radiology, this technique will extend into the coming years and the number of practitioners likely to perform this procedure will increase. The aim of our study was to evaluate, on a cadaveric cohort, the feasibility and the learning curve of ultrasound-guided percutaneous carpal tunnel release.

## Materials and methods

Carpal tunnel releases were performed alternately by a senior radiologist (5 years' experience in musculoskeletal interventional radiology) and by a junior radiologist (2 years' internship in diagnostic radiology, with no experience in interventional radiology). This was carried out at the anatomical laboratory of our faculty, from June to September 2017. Procedures were carried out on unembalmed cadavers. We used a linear-array equipment with an 18 MHz linear probe (My lab Esaote, Esaote, Genova, Italy) for ultrasound guidance. We worked under simulated sterile conditions (probe cover, gloves, clothes). Supplementary materials that were needed for the carpal tunnel release were: a scalpel 11 blade, a 21-gauge needle, a 10-cc syringe, local anesthetic (Lidocaine 1%), and an Acufex 3.0-mm hook knife (010600; Smith & Nephew, London; Fig. 1).

Each session was divided into two successive parts:

1. The ultrasound-guided percutaneous release of carpal tunnel: ultrasound anatomical evaluation was first performed to delineate target structures, bony landmarks, and detect any anatomical variant. We located the “security zone,” between the Guyon canal and the ulnar edge of the median nerve. We realized the skin marking of the proximal and distal limits of the transverse carpal ligament (TCL), evaluated by ultrasound. We notified the length of the



**Fig. 1** Material needed for one procedure, in addition to ultrasound elements and sterilization environment. At the bottom of the image we can see the hook knife (Acufex Smith & Nephew® 3 mm)

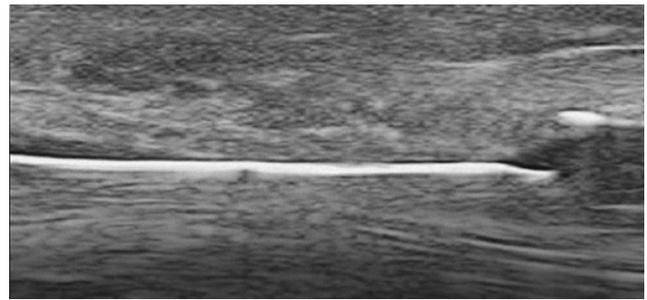
TCL and the presence or absence of the following anatomical variants: variants of the thenar motor branch of the median nerve or muscle hypertrophy of the thenar eminence. The whole procedure was realized under ultrasound control. We performed a hydrodissection of the carpal tunnel using Lidocaine, by an anterograde approach of the skin fold of the wrist with a 21-G needle. A millimetric skin incision was made with a scalpel, at the same cutaneous entry point. The knife was then introduced into the security zone of the carpal tunnel, in a horizontal position, the hook turned to the ulnar edge (Fig. 2). The knife was advanced under the TCL toward its distal limit and outreaching it by a few millimeters. The knife was rotated 90° to place the hook vertically and upward. Then we realized a retrograde section of the TCL, by gradually pulling out the hook knife up to the skin entry point (Fig. 3), and appreciating the resistance of the TCL. It was possible to check the section of TCL by reinserting the hook knife (in horizontal position) or the 21-G needle, and moving it up and down under ultrasound guidance to check the complete section of the TCL. Alternatively, reinjection of Lidocaine in the carpal tunnel would prove the complete section of the ligament when reaching superficial soft tissues. If necessary, a second, and eventually a third passage were realized, aiming to complete the section. The size of the skin incision, the number of knife passages and the duration of each procedure from the first injection of Lidocaine until the knife was withdrawn, were all recorded.

2. Explorative anatomical dissection and evaluation: following the procedure, the wrist was evaluated by open anatomical dissection. The mean evaluation criterion was if the release of the TCL was complete or not (Fig. 4). A release was considered complete only if the entire length and depth of the TCL were sectioned. When the release was incomplete, we described the results obtained in addition to the size and location (proximal or distal) of the missing section. When appropriate, we noted if only the deep layer was sectioned. We checked the absence of damage of the median nerve and its branch of the palmar vascular arch. The presence or absence of anatomical variants was also noted.

All the data were collected on pre-filled forms, which were completed at each stage of the procedure and dissection. Patient details and clinical information were obtained from the medical records and relevant details were entered into an Excel worksheet (Excel 05; Microsoft, Redmond, WA, USA). The statistical analysis was carried out using both commercially available SPSS® Statistical Software (SPSS 11.0 for Windows) and open access Statistical Software R version 2.15.3. A descriptive analysis of the variables included was carried out, analyzing the absolute and relative frequencies (percentages) of the qualitative variables.

## Results

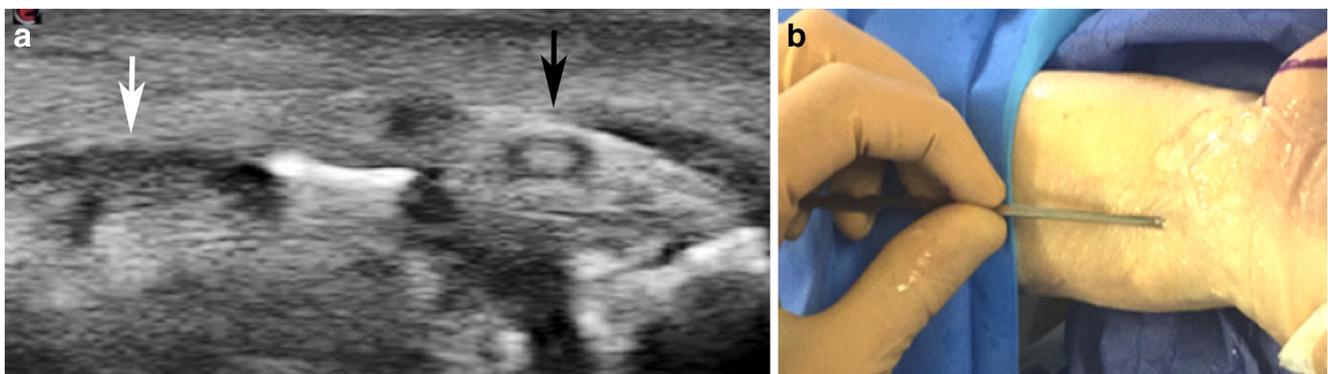
Fourteen carpal tunnel releases were carried out, 7 by a senior radiologist and 7 by a junior radiologist. The 14 patients included were analyzed. The mean duration of the procedure was  $14 \text{ min} \pm 6$ . Five out of 14 sections were complete (37.5%) and the mean section percentage was 76%. Mean length of the retinaculum cut was  $35 \pm 5 \text{ mm}$  (27%). Detailed patient specifics are described in Table 1. Evaluation of data did not allow statistically significant



**Fig. 3** Sagittal ultrasound view of a retrograde section of the transverse carpal ligament (TCL) with the hook in a vertical position

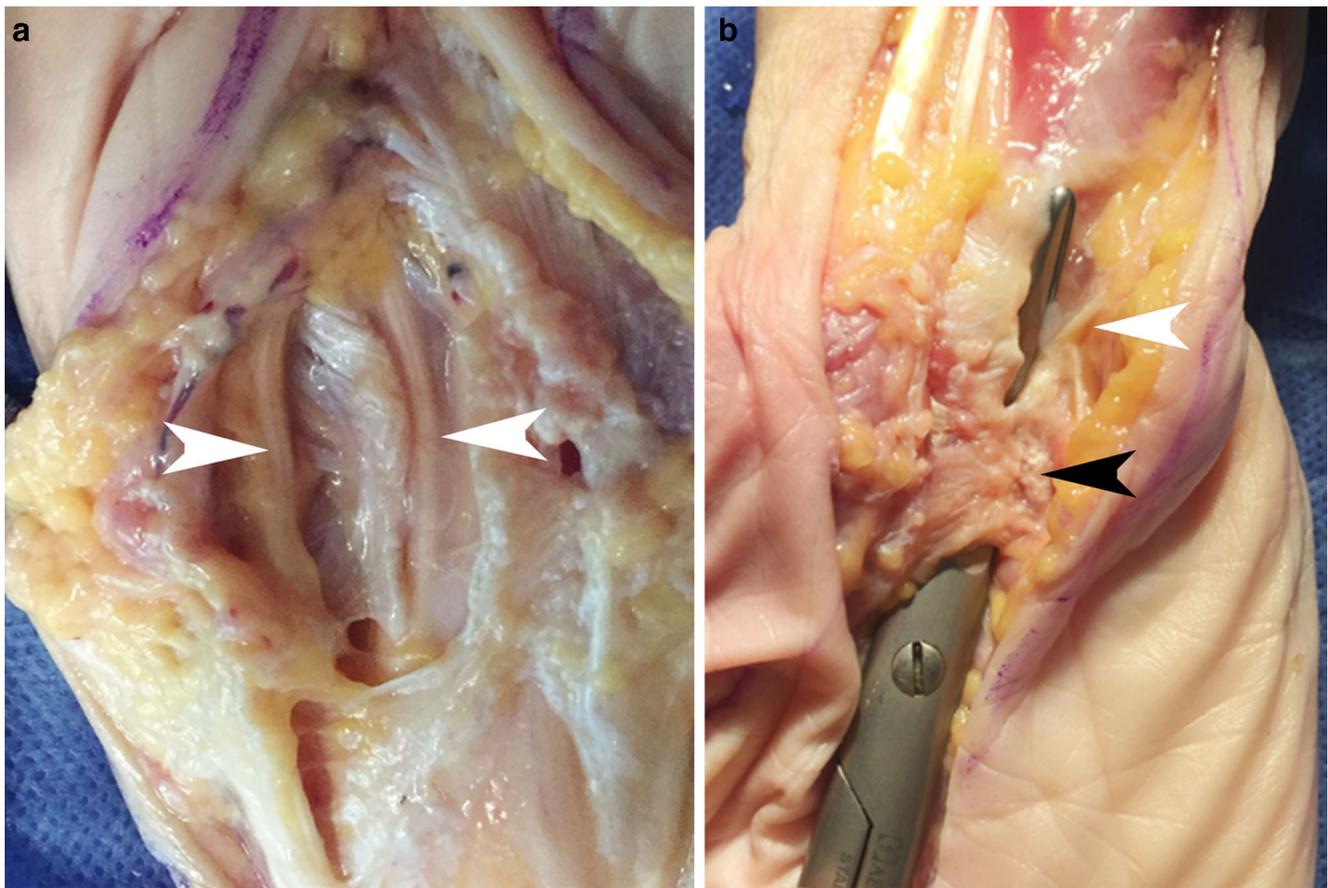
differences to be shown between the junior's and senior's experience of the intervention because of a lack of power.

The senior operator was able to perform a complete release after training on 3 specimens and the junior operator after 4 specimens. No damage of the median nerve or vascular structure was observed upon anatomical dissection. In most of the cases, the release was incomplete because of an incomplete section of distal TCL (9 wrists, 4 for the senior operator and 5 for the junior, 10-mm missing section on average). There were two cases of a section of the deep layer only (by the junior radiologist). The median percentage of the length of TCL release was 73.5% for the senior operator and 63% for the junior operator (Q1 = 57, Q3 = 100 and Q1 = 50 and Q3 = 86 respectively;  $p > 0.05$ ). Learning curves in terms of time of procedure and percentage of TCL released are shown in Figs. 5 and 6 respectively. Several passages were associated with a more frequent complete release (we realized on average two passages per procedure). Median duration was 11 min for the senior operator (Q1 = 8 and Q3 = 13) and 15.5 min for the junior operator (Q1 = 14 and Q3 = 17;  $p > 0.05$ ; Table 2). For the last complete release realized, the duration of the procedure was 11 min for the senior operator and 14 min for the junior operator. The mean size of the skin incision was 3 mm. The length of the TCL evaluated by ultrasound was close to the reality (33 mm evaluated by ultrasound versus 35 mm measured by dissection, on average). Length of TCL, measured by anatomical dissection, varied from 30 to 40 mm.



**Fig. 2** **a** Axial ultrasound view of the knife in horizontal position in the security zone. *White arrow* shows the median nerve, *black arrow* shows

the ulnar artery in the Guyon canal. **b** Photograph showing the knife introduced in the horizontal position (antegrade approach to the wrist)



**Fig. 4** **a** Open anatomy dissection showing a complete section of the TCL. *Arrowheads* show the complete sectioned TCL. **b** Open anatomy dissection showing an incomplete section of the TCL. *White arrowhead*

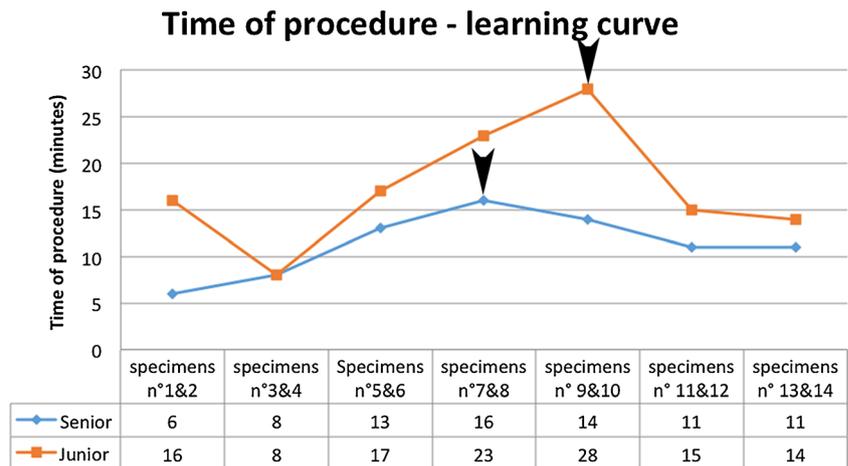
shows the sectioned part of the TCL (proximal) and *black arrowhead* shows the non-sectioned part of the TCL (distal)

**Table 1** Transverse carpal ligament (TCL) releases

Specimen	Operator	Length of TCL, mm	Length of TCL released, mm	Percentage length of TCL released	Details of incomplete release (when appropriate)
1	Senior	35	25	71	29% distal (10 mm)
2	Junior	30	10	33	33% (10 mm) distal and 33% (10 mm) proximal
3	Senior	30	15	50	50% distal (15 mm)
4	Junior	40		50 <sup>a</sup>	Deep section only
5	Senior	30	23	76	24% distal (7 mm)
6	Junior	28		50 <sup>a</sup>	Deep section only
7	Senior	35	35	100	
8	Junior	30	23	76	24% distal (7 mm)
9	Senior	45	30	67	23% distal (15 mm)
10	Junior	40	40	100	
11	Senior	40	40	100	
12	Junior	35	30	86	14% distal (5 mm)
13	Senior	35	35	100	
14	Junior	38	38	100	

<sup>a</sup> Deep section only was considered 50% of release

**Fig. 5** Learning curve of the duration of the procedure. *Arrowheads* show the first complete release, for the senior operator and the junior operator



### Discussion

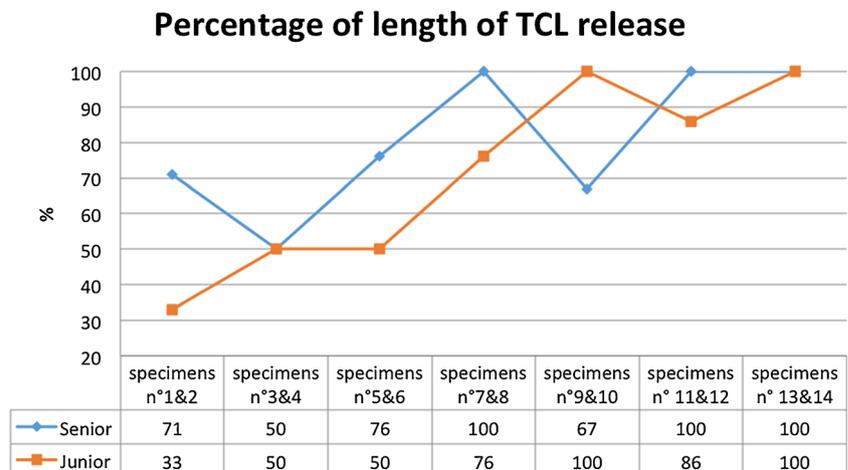
The aim of our study was to evaluate the feasibility and the learning curve of ultrasound-guided percutaneous carpal tunnel release. Our study suggests that this procedure might be safe, efficient, and have a rapid learning curve. To our knowledge, it is the first study to evaluate the learning curve that includes a comparison between a senior radiologist with experience in interventional musculoskeletal radiology, and a junior radiologist. This technique is promising and could permit radiologists to keep taking care of their patients by proposing this alternative to surgery. Furthermore, in the case of failure of ultrasound release, surgery is always possible.

Various techniques described for percutaneous carpal tunnel release under ultrasound guidance [8, 9]. We chose the hook knife technique. This technique appeared to be the easiest to practice, was available in our center, and was shown to be promising in a previous clinical study [6]. Indeed, this new technique simplifies the procedure of various series by eliminating the use of dissection scissors, a trocar, or a Kirschner guide. Using injected anesthetic, hydrodissection is sufficient

to prepare the tunnel for the action of the scalpel [10]. Although in most recent studies, procedures are performed by surgeons or rheumatologists [4, 5], we evaluated the feasibility of such a procedure by an experienced radiologist with ultrasound skills.

Ultrasound was indeed a good tool for evaluating the local anatomy before the intervention, in particular, to predict the length of the TCL as described in the literature [11]. Ultrasound guidance has a real advantage over endoscopic release. It permits full recognition during the procedure (especially the tendons, median nerve, and its branches, canal of Guyon with the ulnar artery), particularly on introduction of the hook knife, whereas initial placement of the trocar is a blinded procedure during endoscopic release. Open surgery allows visualization of these structures but it proves to be more difficult than under ultrasound guidance. This is because during open surgery, the only view possible is through a 1- or 2-cm skin incision. Ultrasound permits a complete view of the carpal tunnel and the determination of different structures is easier for a radiologist who practices diagnostic ultrasound or infiltration of carpal tunnel syndrome. Ultrasound guidance associates the advantage of a comfortable view of the carpal

**Fig. 6** Learning curve of the percentage of length of TCL release. We consider only the deep section as 50% release



**Table 2** Senior operator versus junior operator with regard to duration of procedure (min)

	Senior	Junior	
Specimens 1 and 2	6	16	
Specimens 3 and 4	8	8	
Specimens 5 and 6	13	17	
Specimens 7 and 8	16	23	
Specimens 9 and 10	14	28	
Specimens 11 and 12	11	15	
Specimens 13 and 14	11	14	
Median	11 (Q1 = 8, Q3 = 13)	15.5 (Q1 = 14, Q3 = 17)	$p > 0.05$

Q1 first interquartile, Q2 second interquartile, Q3 third interquartile

tunnel and consequently, more security, in addition to the advantage of a minimal incision (3 mm in our study).

Our experience is that the procedure remains mildly difficult to perform. After acquiring the skills to realize the first complete section, most following sections were complete for both junior and senior radiologists. The learning curve for radiologists is much faster than surgical endoscopic carpal tunnel release [12, 13]. There were 9 incomplete sections, including two cases with a section of the ligament deep layer only. Other incomplete releases were most often due to a lack of section of the distal TCL. This raises the question of the clinical effectiveness of an incomplete section, especially for the deep layer. The study by Stecco et al. reports that the preservation of the superficial layer should not affect the outcome of carpal tunnel release; it might even preserve a useful function [14].

Our study suffers from several limitations. First, the small number of specimens limits the significance of our results, especially because we did not observe, by ultrasound or anatomical dissection, any anatomical variant of the thenar motor branch. On the one hand, this can limit our results owing to the risk of damage increasing according to the anatomical variant (transligamentous thenar motor branch). However, on the other hand, a recent cadaveric study demonstrated that ultrasound is effective for identifying anatomical variations of the median nerve and thenar motor branch [3]. Other limitations are secondary to the cadaveric feature of our study. First, cadaveric rigidity and cold conservation may make the section difficult, providing more resistance than in a living patient. Second, the medical history of wrist surgery or traumatism was unknown. Third, we could not use color Doppler for marking vascular structures, especially the distal palmar arch. This may explain why most incomplete sections were distal, because we were very careful not to injure the palmar vascular arch. In living patients, color Doppler may allow the operator to go more distally with minimal risk.

## Conclusion

To our knowledge, this is the first cadaveric study to evaluate the learning curve between senior and junior radiologists for the ultrasound-guided percutaneous carpal tunnel release. Our findings suggest that this might be a procedure that carries a rapid learning curve for radiologists. All the radiologists practicing ultrasound of the carpal tunnel, for diagnostic or for infiltration treatment, can benefit from the use of a supplementary tool in the care of patients suffering from carpal tunnel syndrome.

## Compliance with ethical standards

**Conflicts of interest** The authors declare that they have no conflicts of interest.

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