Carpal Tunnel Syndrome: Underdiagnosed conditions assessed by ultrasonography

Poster No.: C-1512
Congress: ECR 2013
Type: Educational Exhibit
Authors: C. A. S. Ruano, P. L. Pegado, J. M. G. Lourenco, P. Alves, L. Vieira; Lisbon/PT
Keywords: Normal variants, Education, Ultrasound, Neuroradiology peripheral nerve, Musculoskeletal system, Anatomy, Education and training
DOI: 10.1594/ecr2013/C-1512

Any information contained in this pdf file is automatically generated from digital material submitted to EPOS by third parties in the form of scientific presentations. References to any names, marks, products, or services of third parties or hypertext links to third-party sites or information are provided solely as a convenience to you and do not in any way constitute or imply ECR's endorsement, sponsorship or recommendation of the third party, information, product or service. ECR is not responsible for the content of these pages and does not make any representations regarding the content or accuracy of material in this file.

As per copyright regulations, any unauthorised use of the material or parts thereof as well as commercial reproduction or multiple distribution by any traditional or electronically based reproduction/publication method is strictly prohibited.

You agree to defend, indemnify, and hold ECR harmless from and against any and all claims, damages, costs, and expenses, including attorneys' fees, arising from or related to your use of these pages.

Please note: Links to movies, ppt slideshows and any other multimedia files are not available in the pdf version of presentations.

www.myESR.org
Learning objectives

This poster aims to demonstrate the sonographic presentation of Carpal Tunnel Syndrome and to highlight the value of ultrasonography when determining Carpal Tunnel Syndrome etiology, emphasising the importance of structural anomalies on median nerve compression.
Background

Carpal tunnel syndrome (CTS) is the most frequent peripheral entrapment neuropathy, believed to be present in 3.8% of the general population. Patients usually experience burning pain, numbness and a tingling sensation along the distribution of the median nerve, symptoms that tend to be worst at night. It occurs more frequently in 40 to 60 year old females and is commonly bilateral. It is a frequent entity in diabetic patients, with a prevalence rate of 14% and 30% in patients without and with diabetic neuropathy, respectively. In pregnancy its prevalence has been reported to be around 2%. [1]

CTS remains mainly an idiopathic syndrome, although environmental (namely occupational) and medical risk factors (for instance, heart and renal failure, hypothyroidism and obesity) may be associated with this condition. In rare cases, CTS may also be motivated by a wide range of extrinsic causes, such as congenital abnormalities (bifid median nerve, persistent median artery or accessory muscles) and acquired diseases (tenosynovitis, ganglion cyst, carpal bone malalignment and bone fractures).

Concerning the diagnosis of CTS, there is no accepted "gold standard". It is usually based on clinical history and examination, and confirmed by electrophysiological testing. Although the latter is the most sensitive and accurate technique diagnosing median nerve impairment it does not assess its anatomy. Contrarily, ultrasonography (US) has proven to be able to discriminate between normal and pathologic nerves, as well as to identify various causes of neuropathy in non idiopathic CTS. [2]

Several studies have demonstrated that the combination of US with clinical features and electrophysiological studies were more sensitive and specific in diagnosing CTS than clinical evaluation or electromyography (EMG) alone. [2] Recent literature also states that US is a precise method for displaying structural abnormalities that may cause CTS: bifid median nerves are described in 2-13% CTS patients, persistent median arteries in 9-13%, tenosynovitis in 6% and accessory muscles in 3%. [3]

Although uncommon, the presence of these structural abnormalities and anatomic variants are of extreme therapeutic interest, as they may alter the choice of the interventional approach. Moreover, these variations may be the cause of failed surgical interventions.
Anatomic revision of the carpal tunnel

The carpal tunnel is an osteofibrous tunnel, delimited dorsally by the carpal bones and volarly by the flexor retinaculum, or transverse carpal ligament (TCL). This tunnel contains, apart from the median nerve, four tendons from the flexor digitorum superficialis, four tendons from the flexor digitorum profundus and the tendon of the flexor pollicis longus.

The retinaculum, which is approximately 3 to 4 cm wide, is attached to the tuberosity of the scaphoid and the pisiform proximally and to the tubercle of the trapezium and hook of the hamate distally. The median nerve lies immediately under the retinaculum, volarly to the second and third flexor tendons and medially to the flexor pollicis longus tendon. (Fig.1) Distally to the carpal tunnel, the median nerve divides into four sensory branches to the digits (which supply the first, second and third digits and the radial half of the forth) and one motor branch to the thenar muscles, which can pierce or wrap around the distal TCL.

The normal median nerve is composed of bundles of hypoechoic fascicles, contained within a hyperechoic epineurium. Each fascicle is, in turn, contained within a hyperechoic perineurium. This arrangement results in a honeycomb or "bunch of grapes" appearance on the transverse US scans. (Fig.2) Doppler studies show no detectable vascularity in the normal nerve.

Sonographic assessment of CTS

US criteria for compression include nerve swelling at the distal forearm or proximal tunnel, nerve flattening in the distal carpal tunnel and palmar bowing of the flexor retinaculum. Compressed nerves may exhibit loss of the normal fascicular pattern and reduced echogenicity.

Compression of the median nerve leads to an enlargement of its cross-sectional area (CSA).

A CSA measurement greater than 9 mm$^2$ at the level of the proximal tunnel is reported to be the best criterion for median nerve compression diagnosis, while measurements smaller than 8 mm$^2$ reliably exclude CTS. [4,5]
CSA may be calculated directly, by tracing the margins of the median nerve with electronic callipers, or indirectly, by measuring the long and short axis and applying an ellipse area formula.[4] Median nerve measurements should be obtained within, rather than outside, the echogenic epineurium.[6] (Fig.3)

A variant approach to the diagnosis of CTS has been reported (Fig. 4). It was designed to minimize the differences in measurement technique and account for the standard deviations in normal nerve cross sectional areas (6.1 - 10.4 mm²) in various populations, allowing the patient to provide its own internal control. This approach relies on calculating the difference between CSA at the wrist (at the level of maximal swelling in the carpal tunnel - CSAc) and at the distal forearm (at the proximal third of the pronator quadratus muscle - CSAp). At this level, the median nerve can be identified between the flexor pollicis longus tendon and the flexor digitorum superficialis tendon.

The difference between the two measurements (#CSA = CSAc - CSAp) proved to be significantly higher in CTS patients when compared to healthy individuals. Some authors report a cut-off point of 2 mm² as having the highest sensitivity and specificity for CTS diagnosis. [5] However, opinions differ on this matter and more studies are needed to validate this approach as to define the perfect cut-off value.

Other reported features, apart from enlarged median nerve CSA, are diminished transverse and longitudinal nerve movement and increased nerve vascularity in Power Doppler US scans.

**Less common causes of CTS**

Idiopathic CTS is typically bilateral, with the dominant hand usually more severely affected. In unilateral idiopathic CTS, the affected hand is typically the dominant one.

In case of unilateral or severe CTS, especially in the non-dominant hand, one should consider the presence of a specific underlying cause. As in these cases clinical examination and electrophysiological tests will present similar results to those of idiopathic CTS, the patient should be referred to US evaluation for an accurate diagnosis.

**Congenital abnormalities**

- Bifid median nerve
A bifid median nerve is an anatomic variation reported extensively in the surgical literature. Because of its relatively higher CSA, the bifid median nerve may be more predisposed to compression than the non-bifid nerve. This anomaly has been reported in 0.8 - 2.8% of CTS patients and is generally accompanied by a persistent median artery. [7] (Fig. 5)

Bifid median nerve CSA measurements are obtained by summing the CSA of the lateral and medial branches of the bifid nerve. The most agreed upon threshold for diagnosing CTS in bifid median nerves is 11 mm$^2$, although some authors report 12 mm$^2$. In the presence of a median artery, care should be taken to exclude it from the CSA measurement. [7]

- **Persistent median artery**

The median artery, along with the interosseous artery, is responsible for the blood supply to the forearm and hand in the embryonic development. After the 8th week of gestation it atrophies to a small vessel accompanying the median nerve, leaving radial and ulnar arteries responsible for the vascularisation. In many healthy individuals, the median artery may not undergo reduction but instead persist as a sizable vessel. [8] (Fig. 6)

Preoperative diagnosis of this condition is of great importance as the median artery is immediately dorsal to the transverse carpal ligament and may be injured on carpal tunnel release surgery, with risk of postoperative bleeding, progressing to hematoma and fibrosis, and eventually leading to CTS recurrence.

- **Accessory muscles**

Accessory muscles are fairly common anatomic variants. Though extensively described in the literature, they are commonly disregarded in radiological studies. While most patients with accessory muscles are asymptomatic, some may present clinical symptoms, namely due to compression of a neurovascular bundle in an osteofibrous tunnel.

Variants in *Palmaris longus* muscle anatomy and the presence of an accessory *Flexor carpi radialis brevis vel profundus* muscle (Fig. 7) have been associated with CTS. [9] When assessing unilateral CTS one should not overlook these muscles, as their recognition is essential to adequate treatment.

- **Congenital hand deformities**

Patients with congenital hand abnormalities may have altered contour or diminished area of the carpal tunnel, leading to compression of the median nerve. (Fig. 8)
**Acquired conditions**

Acquired conditions such as ganglion cysts, tenosynovitis, rheumatoid nodules, lipomas, nerve sheath tumours and vascular tumours may also increase the pressure in the carpal tunnel, causing compression of the median nerve. (Fig. 9,10,11,12)

Other extrinsic factors that may alter carpal tunnel contour are fractures of the distal radius and carpal bone malalignment. [10]

**US evaluation after Carpal tunnel release surgery**

Carpal tunnel release (CTR) surgery is the main surgical treatment for CTS. It is based on sectioning the transverse carpal ligament to reduce interstitial pressure in the tunnel. Although CTR surgery has excellent long-term outcomes, some patients will not be relieved of their symptoms. This may be due to incomplete sectioning of the retinaculum (early complication) or scar tissue formation (late recurrence). [10] (Fig. 13)

In addition, some patients will remain symptomatic by the persistence of the described above anatomic variants and space-occupying alterations. Hence preoperative US wrist evaluation is of extreme importance in CTS treatment planning.
**Fig. 1:** Anatomy of the carpal tunnel. Transverse US scans (a,b) and corresponding drawings (c,d), showing the anatomy of the carpal tunnel, at its inlet (a,c) and outlet (b,d). The tunnel is delimited proximally (a,c) by the scaphoid (S) and the pisiform (P) and distally (b,d) by the tubercle of the trapezium (T) and the hook of the hamate (H). The flexor retinaculum (dashed line/arrowhead) forms the roof of the carpal tunnel. The flexor digitorum superficialis (FDS/S) and flexor digitorum profundus (FDP/P) tendons, as well as the median nerve (dotted line/open arrow) extend through the carpal tunnel. The flexor pollicis longus tendon (FPL) travels through the carpal tunnel, lateral to the median nerve, while the flexor carpi radialis tendon (FCR) is placed in a separate compartment between two layers of the flexor retinaculum.

© Department of Radiology, Centro Hospitalar Lisboa Central, Lisbon, Portugal

**Fig. 2:** Median nerve. Transverse (a) and longitudinal (b) US scans of a normal median nerve (arrows) showing the characteristic fascicular appearance. FDS = flexor digitorum superficialis; FDP = flexor digitorum profundus.
**Fig. 3:** Carpal tunnel syndrome. Transverse (a) and longitudinal (b) US scans of a patient with CTS, showing a hypoechoic median nerve without the normal fascicular pattern, with a CSA of 16 mm² measured at the level of the proximal tunnel. CSA measurements should be obtained within (dotted line) rather than outside the echogenic epineurium (open arrows).

**Fig. 4:** Median nerve CSA measurements of a patient with CTS. Transverse US scans of a patient with CTS, showing median nerve (arrows) CSA measurements at the distal forearm (a), between the flexor pollicis longus (FPL) and the flexor digitorum superficialis (FDS), and at the wrist (b), at the level of maximal nerve swelling. #CSA = 13 - 8,5; #CSA =4,5 mm².
**Fig. 5:** Bifid median nerve and persistent median artery. Transverse US scans of two patients with bifid median nerves (dotted lines), in b) accompanied by a persistent median artery (arrow).

© Department of Radiology, Centro Hospitalar Lisboa Central, Lisbon, Portugal

**Fig. 6:** Bifid median nerve, persistent median artery and vein. Transverse Gray scale (a) and Colour Doppler (b) US scans of a patient with a bifid median nerve (arrow), a persistent median artery and corresponding vein (colour Doppler signal).

© Department of Radiology, Centro Hospitalar Lisboa Central, Lisbon, Portugal
Fig. 7: Flexor carpi radialis brevis vel profundus muscle. Drawing illustrates the Flexor carpi radialis brevis vel profundus muscle (star), arising from the distal radius, coursing superficially to the pronator quadratus muscle (circle), and passing deep to the flexor retinaculum (arrowheads).

© Department of Radiology, Centro Hospitalar Lisboa Central, Lisbon, Portugal
Fig. 8: Unilateral hand hypoplasia. Transverse (a) and longitudinal (b) US scans of a 4 year-old boy with a small right hand and unilateral CTS, in which median nerve (open arrows) compression resulted from decreased carpal tunnel area.

© Department of Radiology, Centro Hospitalar Lisboa Central, Lisbon, Portugal

Fig. 9: Rheumatoid nodule. Transverse (a) and longitudinal (b) US scans of a patient with long-standing Rheumatoid Arthritis and unilateral CTS, in which a hypoechoic nodule (open arrows) was identified, adjacent to and dislocating the median nerve (dashed arrows). Additionally, this patient had two persistent median arteries.

© Department of Radiology, Centro Hospitalar Lisboa Central, Lisbon, Portugal
Fig. 10: Median nerve schwannoma. Longitudinal (a) and transverse US scans of a patient with unilateral CTS symptoms, showing an oval-shaped, homogenous hypoechoic tumour (open arrows) arising from the median nerve (dashed arrows).

© Department of Radiology, Centro Hospitalar Lisboa Central, Lisbon, Portugal

Fig. 11: Fibrolipomatous hamartoma of the median nerve. Transverse (a) and longitudinal (b) US scans of a 7 year-old girl with unilateral symptoms of CTS, showing progressive enlargement of the median nerve (open arrows), with hyperechoic fat interspersed between the hypoechoic nerve fascicles. CSA at the distal forearm: 6 mm2; CSA at the distal carpal tunnel: 115 mm2.

© Department of Radiology, Centro Hospitalar Lisboa Central, Lisbon, Portugal
**Fig. 12:** Gouty tophus. Transverse US scans of a 49 year-old male with untreated long-standing gout and unilateral symptoms of CTS, showing a hyperechoic amorphous mass (open arrow) delimited by a hypoechoic rim (arrow), displacing and compressing the median nerve (dashed arrow).

© Department of Radiology, Centro Hospitalar Lisboa Central, Lisbon, Portugal

**Fig. 13:** Post-release alterations. Longitudinal US scans of two CTS patients previously submitted to CTR surgery, in which post-operative fibrosis (arrows) lead to compression of the median nerve (dashed arrows) and CTS recurrence.

© Department of Radiology, Centro Hospitalar Lisboa Central, Lisbon, Portugal
Conclusion

Ultrasonography yields high diagnostic accuracy and should complement classic CTS evaluation by screening for structural abnormalities at the wrist, especially in patients with unilateral or severe CTS.
References