The Egyptian Journal of Hospital Medicine (April 2023) Vol. 91, Page 5394- 5398

Ultrasound Diagnosis of Carpal Tunnel Syndrome: Review Article

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ABSTRACT

Background: Carpal tunnel syndrome (CTS) is disorder that causes discomfort in the hand and arm, including numbness and tingling. Carpal tunnel syndrome manifests itself when there is an impingement on the median nerve as it passes through the wrist. Ultrasound is becoming more and more used as a diagnostic imaging technique in the medical field. The sonographic evaluation allows for the visualisation of various structures with a horizontal resolution of 0.1 mm and a vertical resolution of 0.2 mm.

Objective: Review of literature about carpal tunnel syndrome ultrasound diagnosis.

Methods: To learn more about ultrasound for diagnosing carpal tunnel syndrome, we searched scientific journals and resources including PubMed, Google Scholar, and Science Direct. However, only the most recent or thorough studies were taken into account between August 1984 and August 2020. The authors also evaluated the value of references obtained from other novels in the same genre. Due to a lack of resources, documents written in languages other than English have been ignored. Dissertations, oral presentations, and conference abstracts were all mostly agreed upon not to be scientifically valid.

Conclusion: The examination of CTS using US has becoming increasingly common. Ultrasound (US) among cases patients who had electromyographic (EMG) results of CTS has the advantage of detecting alterations of structure as well as swelling of nerve, however it could also be utilized for visualization of other abnormalities that EMG couldn't detect.

Keywords: Ultrasound diagnosis, Carpal tunnel syndrome.

INTRODUCTION

Ultrasound (US) is being used to check for CTS. Patients with electromyographic (EMG) findings of CTS can benefit from ultrasound (US) because it can detect swelling of nerves, changes of the structure as well as its ability of visualization of other disorders that EMG cannot [(1)].

Pain, and tingling as well as numbness, in the affected hand are classic symptoms of carpal tunnel syndrome (CTS), which are a frequent medical ailment. When the median nerve in the wrist is compressed, it leads to symptoms known as carpal tunnel syndrome [(2, 3)], which is characterized by a loss of strength or numbness in the afflicted area. CTS affects at least 3.8% of those who have hand discomfort, numbness, or tingling [(4)].

Medical exams and electrophysiological testing are used to detect the most prevalent cause of these symptoms, idiopathic CTS. An additional 276 cases of CTS are reported per year in the United States. The annual incidence rate for women is 9.2%, while the rate for men is 6% [(4)]. CTS affects people of all ages, but it's more common among middle-aged and older persons. The United Kingdom, like many other European countries, has a higher than average rate of CTS (between 7% and 16%) compared to the United States (5%) [(5)].

Median nerve in carpal tunnel as a result of mechanical force, high pressure, or ischemia is a major cause of carpal tunnel syndrome. When it comes to high pressure, average pressure is between 2 and 10 mmHg. The fluid pressure in the carpal tunnel is highly sensitive to wrist motion. Therefore, the pressure increases by more than ten times during the extension, and by eight times during the flexion of the wrist [(6)]. Pain and tingling along the median nerve's path are hallmark symptoms of CTS. It is not uncommon for people to conceal the palmar surfaces of their thumb, index, middle, and half of their ring finger. The ulnar nerve terminates at the end of the little and ring fingers, hence those two should be left out [(7)].

Ultrasound is becoming more and more used as a diagnostic imaging technique in the medical field. Sonographic analysis allows for the visualization of various structures by a horizontal resolution of 0.1 mm and a vertical resolution of 0.2 mm. Since it acquires a multi-layered image of the investigated region, it is practically the only imaging approach that permits a dynamic examination. The use of ultrasound (US) is risk-free because it does not involve the use of ionising radiation, and it may be performed anywhere with a portable device. Its versatility in testing allows for monitoring of progress throughout time. At last, it's available at a reasonable price. Increases in picture quality and the creation of fresh examination strategies can be attributed to technological advancements, the development of cutting-edge machinery and the deployment of miniature transducers that operate at extremely high frequencies. It's important to do that so that ultrasound can be used routinely to examine the hand, wrist, and carpal tunnel [(8)].

If you want to take a picture of a nerve in your arm or leg, you'll need a linear probe with a frequency higher than 12-14 MHz and a resolution lower than 0.3 mm. A convex probe can help ultrasonic waves travel further and reach more structures, which is useful for assessing

Received: 11/01/2023
Accepted: 14/03/2023

deep nerves or for people who are overweight [9]. Gelous agar spacers aid in the investigation of superficial nerves. Such tools enhance nerve imaging in situ by bringing the nerve into focus of the ultrasonic beam and by facilitating better contact between the probe and uneven bone surfaces. Such augmentation is especially helpful in testing the little nerves in the wrist (Figure 1) [10].

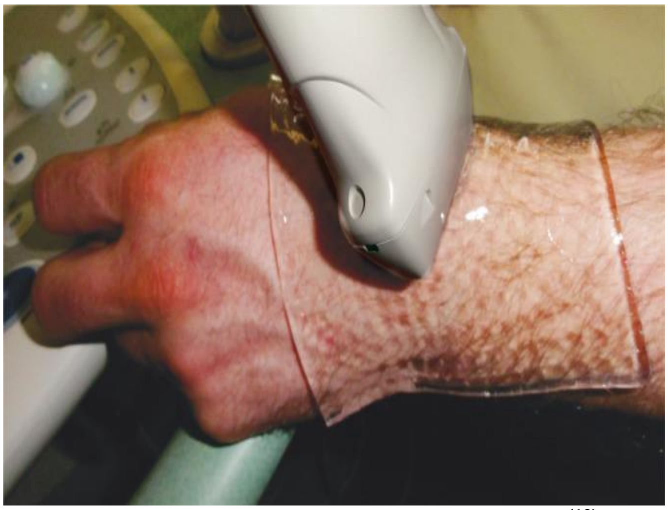

Figure (1): Distancing adaptor made from agar [10].

Patients with carpal tunnel syndrome are examined sonographically using a linear transducer operating at 8-14 MHz or 6-18 MHz. Patients are typically examined with their forearms propped up on a level surface, wrists relaxed, and fingers slightly flexed. In CTS, the median nerve is likely to undergo morphological alterations due to compression from nearby squishy components. When a nerve is compressed, its volume decreases at the site of compression while it swells proximally and sometimes distally. As a result, the median nerve's cross-sectional area (CSA) is the most common ultrasonography standard for identifying CTS. Tracing the median nerve as it passes through the hyperechoic epineurium at right angles to the nerve's long axis reveals its cross-sectional size. The median nerve is easily identifiable at the start of the carpal tunnel. The carpal tunnel's middle and end points are especially difficult to visualize. The thick flexor retinaculum in the distal forearm and palm makes the median nerve there more difficult to access than in the proximal palm [11].

In patients with CTS, the median nerve appeared to take on an hourglass form, with a narrower cross-sectional area within the carpal tunnel compared to its extremities. Median nerve has been stretched from its origin to its termination. When attempting to release pressure in the carpal tunnel, surgeons often notice this problem [12].

Since it is the most easily visible on ultrasonography, the cross-sectional area of the median nerve in the proximal carpal tunnel is the most reported ultrasonography parameter used to diagnose CTS. According to a systematic review, level A evidence suggests that the cross-sectional area of the median nerve in the wrist can be used to diagnose CTS [13].

Ultrasound cross-sectional area cutoff values range widely in the literature, from 9 to 14 mm^2 [12]. The sensitivity was between 57% and 94%, and the specificity was between 57% and 98%. One meta-analysis found that ultrasound's overall sensitivity and specificity for diagnosing CTS were 76% and 86%, respectively [14]. Overall, diagnosis accuracy averaged 82.2% [15]. Variations in disease severity, as well as nerve size as influenced by factors such as race, height, quality of visualization, weight, sex, as well as age, all contribute to variances in diagnostic accuracy and cutoff values. In reality, disparities in nerve size across age, sex, and race have received little attention [12].

The CSA can be used to diagnose CTS, although there are limits due to changes in anatomy between patients. Researchers recently established a threshold of 2 mm^2 when comparing the largest CSA within the carpal tunnel to the CSA of the proximal median nerve at the level of the pronator quadratus. However, "delta CSA" has only been utilized in a few of studies for the diagnosis of CTS [16].

Another way to evaluate focal nerve enlargement is by comparing the cross-sectional area of the median nerve at the wrist and the forearm. In that research, the median nerve was sectioned off at the wrist and again around 12 centimeters up from the hand. Patients diagnosed with CTS had a wrist-to-forearm ratio of 2.1 $\pm$ 0.5, compared to 1.0 $\pm$ 0.1 in healthy participants. Patients with a wrist-to-forearm ratio of 1.4 or higher were found to have a 100% sensitivity for identifying CTS. If the problem is only present on one side, the median nerve size on that side could be compared to the healthy side. Using median nerve CSA measurements in a standardized manner to establish a CTS diagnosis is a potential solution [17].

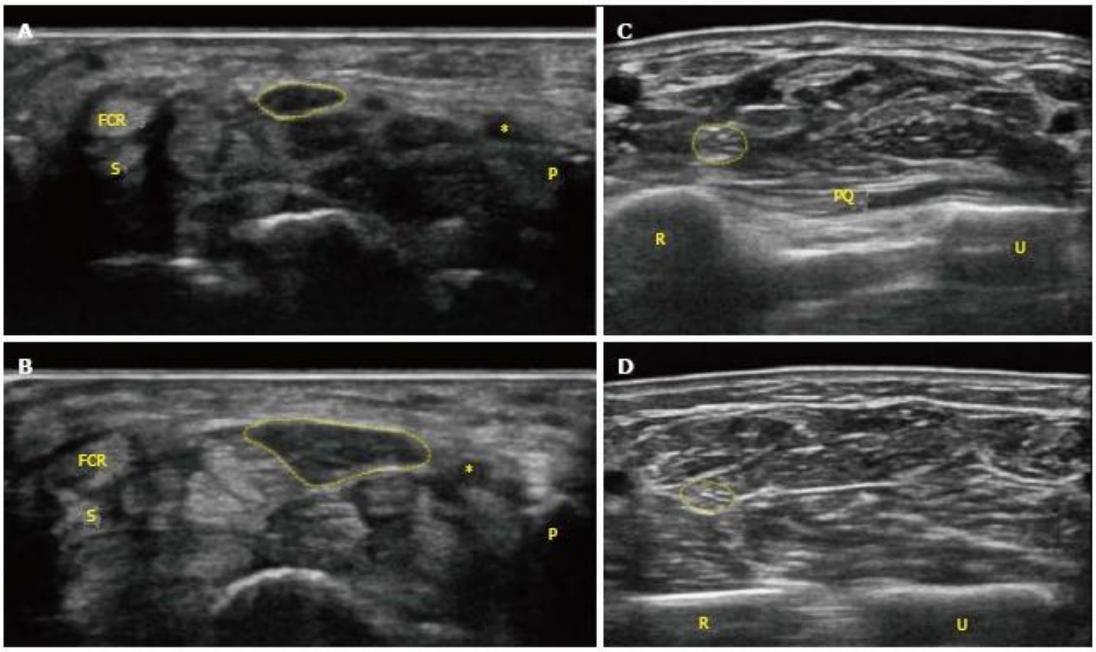

Figure (2): Carpal tunnel syndrome: transverse pictures in a seventy nine years old case [18].

Other characteristic parameters of CTS:

Sonography can detect CTS by observing changes in transverse carpal ligament thickness, dynamical testing reveals reduction in longitudinal excursion, flattening of the median nerve, and palmar bowing of the flexor retinaculum [19, 20]. Also, since CTS with a higher CSA is linked to increased blood flow and decreased echogenicity through median nerve, the vascularity of a nerve can be tested with Doppler sonography to aid in the diagnosis of CTS [21, 22].

Despite the prevalence of CTS, there is currently no quantitative scoring system that is universally recognized as providing reliable measurements of hypervascularity and hypoechogenicity of the median nerve [23].

The US Preferred Elastography Technique is Shear Wave:

Currently, the gold standard is real-time strain elastography, this simultaneously displays a B-mode picture and tissue elastography. Due to its dependence on the operator, it cannot be used to determine an intrinsic elastic modulus [24]. Real-time strain elastography requires a reference region of interest (ROI) to obtain the relative strain ratio of tissue, which can be challenging or impossible to obtain in the musculoskeletal system due to anatomical constraints [25]. Quantitative, noninvasive, and essentially operator-independent, shear wave elastography can be used to evaluate muscle and tendon [26].

Elastography in CTS:

Multiple ultrasound elastography investigations have analysed mechanical alterations in the median nerve due to CTS [27]. A recent meta-analysis demonstrated that patients with CTS consistently showed stiffer median nerves at the wrist level compared to healthy controls, independent of the ultrasound elastography mode used [28].

The extent to which the median nerve's material properties were altering was determined by measuring strain, strain ratio, shear wave velocity, and shear modulus. Distinct ultrasound systems use different measurement concepts, which helps explain why the cutoff values vary from technique to method. The most widely used parameter for strain imaging is median nerve strain. Mean tissue strain was shown to be significantly lower in the CTS patients group compared to the healthy controls in various investigations using strain elastography [29].

Although no details were given about the precision, computations indicated that the strain measurements were 56.5% to 70% accurate for cutoff values of 0.06 to 0.19. One other application of strain elastography is the analysis of elastographic images by measuring pixel colours. CTS subjects tended to have more blue pixels (representing more robust neurons) and less red pixels (indicating softer nerves) [30].

Instead of assessing the absolute stiffness of the nerve, as is done with cross-sectional area, it has been proposed that CTS be diagnosed by comparing the stiffness of the nerve at the wrist to that at the forearm [30]. To account for the effect of applied force on strain measurement data, a term called the strain ratio is used to evaluate the relative strain of the median nerve in comparison to other structures [29]. Different research employed the use of standardized strain measurement equipment that later improved with an ultrasonic pressure monitor. Strain with applied force can be assessed quantitatively using this apparatus because of its improved reproducibility of applied force and transducer displacement (Figure 3) [12].

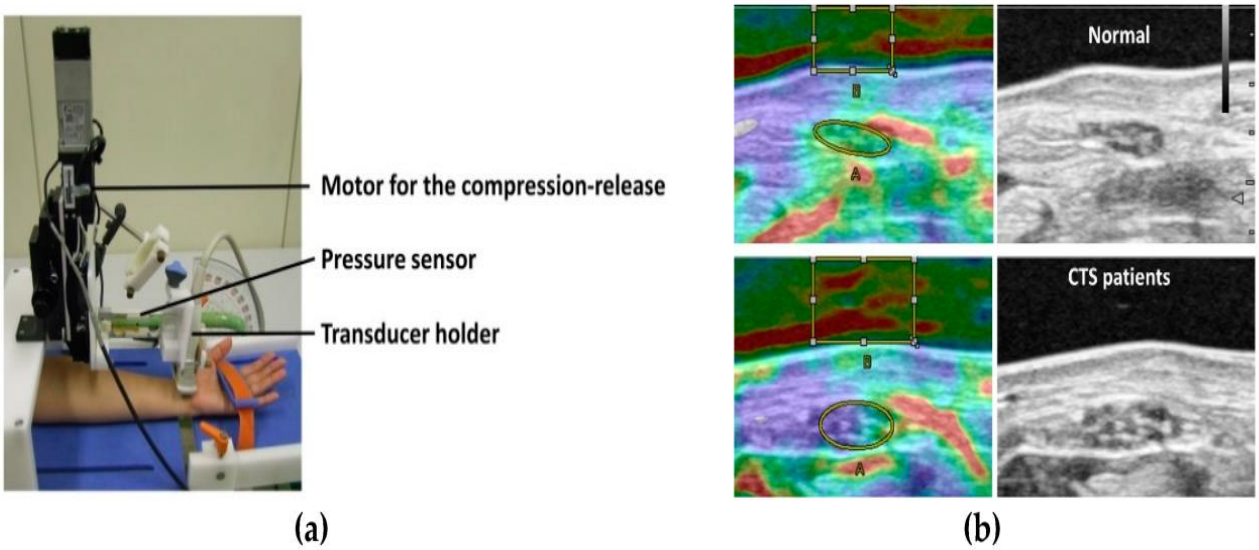

Figure (3): Median nerve strain can be quantitatively measured using a pressure-monitoring ultrasound devices [12]. Shear wave elastography tests showed that CTS sufferers had a much higher shear modulus than healthy controls [31]. The longitudinal image obtained from shear wave elastography is highly attuned to variations in median nerve elasticity. By measuring the speed at which shear waves travel, shear wave elastography can provide an estimate of tissue stiffness. When comparing the median nerve shear modulus of those with CTS (66.7 kPa) and those without CTS (32.0 kPa), there was a statistically significant difference; setting the cutoff value at 40.4 kPa resulted in a 91.7% accuracy rate in the quantitative analysis [31].

Chronic nerve compression is associated with intra-neural edoema, peri-neural thickening, and nerve fibre changes that ultimately result in Wallerian degeneration [32].

The quantitative visualisation of changes in tissue elasticity made available by ultrasound elastography has potential clinical applications when nerve swelling is present. Tissue hardness data obtained via ultrasound elastography is a therapeutically relevant marker for indicating median nerve and tissue histological alterations [12].

CONCLUSION

The examination of CTS using US has becoming increasingly common. Ultrasound (US) among cases patients who had electromyographic (EMG) results of CTS has the advantage of detecting alterations of structure as well as swelling of nerve, however it could also be utilized for visualization of other abnormalities that EMG couldn't detect.

Supporting and sponsoring financially: Nil.
Competing interests: Nil.

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