SCIENTIFIC ARTICLE

Use of Ultrasound in Patients With Carpal Tunnel Syndrome: A Cost-Effective Solution to Reduce Delays in Surgical Care

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Purpose Currently, electrodiagnostic testing, which comprises electromyogram (EMG) and nerve conduction studies (NCS), is the most commonly used method for confirming the clinical diagnosis of carpal tunnel syndrome (CTS). Electromyogram and NCS can be costly, can require multiple visits, may induce anxiety, and may be painful for patients. The purpose of this study was to determine whether replacing EMG/NCS with ultrasound (US), performed by the treating surgeon, to diagnose CTS decreases time to surgery and the number of office visits.

Methods We retrospectively reviewed a database that consisted of patients who presented to our department with numbness and/or tingling in the hand(s). We assessed the patients' histories for any subsequent carpal tunnel release, dates of diagnosis, dates of surgery, the number of CTS-related medical visits, and diagnostic methods employed. A fellowship-trained hand surgeon performed US examination, and the patients were referred for EMG/NCS testing. We collected data prior to surgery using the Boston Carpal Tunnel Questionnaire to evaluate symptom severity scale and functional status scale scores. We performed linear regression to assess differences in the time to surgery and the number of medical visits prior to carpal tunnel release.

Results Patients who had the diagnosis confirmed by the surgeon using US (n = 34) underwent surgical intervention 3−4 weeks earlier, with 1.8 fewer medical visits on average than the number of medical visits for those who had their diagnosis confirmed using EMG/NCS (n = 98).

Conclusions If a confirmatory method for the diagnosis of CTS is required or desired by the treating surgeon, surgeon-conducted US might have an impact on the efficiency of care for patients with CTS. *(J Hand Surg Am. 2021;■(■):1.e1-e6. Copyright © 2021 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Diagnostic IV.

Key words Carpal tunnel syndrome, diagnostics, electrodiagnostic testing, health care costs, ultrasound.

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Carpal tunnel release (CTR) is one of the most common surgical procedures performed in the United States, with over 500,000 procedures performed annually.[1] Carpal tunnel release is widely regarded as the most effective surgical treatment for carpal tunnel syndrome (CTS).[2] Accounting for direct and indirect costs, a unilateral open CTR surgery in the United States has a mean total cost of $2,179.[3] Electrodiagnostic testing, which comprises nerve conduction studies (NCS) and electromyography (EMG), has been a common approach for the diagnosis of CTS. However, according to the results of a blinded, prospective cohort study, ultrasound (US) showed superior positive and negative predictive values compared with EMG/NCS, 94% versus 89% and 82% versus 80%, respectively.[4] Similarly, US resulted in a sensitivity of 89% and a specificity of 90% compared with EMG/NCS, which had a sensitivity of 89% and a specificity of 80%. These findings suggest that US can help diagnose CTS with a comparable or greater level of accuracy compared with EMG/NCS.[4] It should also be noted that multiple studies have shown no added benefit of performing additional diagnostic testing for CTS, particularly in patients with a high pretest probability.[5,6]. Despite this evidence, many surgeons continue to prescribe EMG/NCS.[7]

Two recent studies demonstrated that prereferral and postreferral EMG/NCS delayed the time to specialist evaluation and the time to CTR. However, these studies did not evaluate the role of US in the diagnostic workup of CTS.[7,8] The current study aimed to determine whether the use of US by surgeons to confirm the diagnosis of CTS decreases time to surgery and the total number of medical visits compared with the use of EMG/NCS. Our null hypothesis was that there is no significant reduction in the time to surgery or the total number of medical visits when US is used to confirm the diagnosis of CTS compared with when EMG/NCS is used.

MATERIALS AND METHODS

Following institutional review board approval, a retrospective study was conducted on patients who presented to the Department of Orthopaedics, University of Pittsburgh Medical Center, with numbness and tingling in the hand(s) between 2013 and 2018. The patients were at least 18 years of age and without history of CTR surgery. In general, 1 surgeon refers all patients with symptoms consistent with CTS for EMG/NCS. The senior author (J.R.F.) does not routinely refer patients with symptoms consistent with CTS and instead performs a US examination. After obtaining written consent, the patients completed baseline assessments evaluating CTS using the Boston Carpal Tunnel Questionnaire, a frequently used measure for self-reported symptom severity scale and functional status scale scores.[9] Additional information was collected on age, sex, ethnicity, and body mass index. Patient care was characterized according to the date of CTS diagnosis, diagnostic method (US vs EMG/NCS), the number of medical visits prior to surgery, the date of surgery, and the severity of CTS. The electronic medical records at our institution provide access to all medical visit details and testing results at our institution and other institutions in the area.

Electromyography and NCS were conducted by a certified EMG/NCS physician. All EMG/NCS tests were performed according to the guidelines set by the American Association of Neuromuscular and Electrodiagnostic Medicine.[10] The diagnosis of CTS was confirmed using EMG/NCS and severity graded based on the American Association of Neuromuscular and Electrodiagnostic Medicine's criteria by a board-certified physician.

The US measurements were performed by a fellowship-trained hand surgeon using a 15-6 MHz linear-array transducer (SonoSite M Turbo; SonoSite). The patients were instructed to sit in a comfortable position, with the forearm supinated and the hand and wrist in a relaxed, neutral position. This results in mild flexion at the metacarpophalangeal and proximal interphalangeal joints. A US probe was positioned perpendicular to the long axis of the forearm, and the cross-sectional area of the median nerve was measured at the level of the pisiform using the trace function.[11,12] The borders of the median nerve were defined as the area within the hyperechoic epineurium.[13] Based on previous studies, a cross-sectional area of $\geq$10 mm^2 was considered positive for the diagnosis of CTS.[10–13]

The analyses were conducted on a subset of patients from the CTS database based on the following criteria (Fig. 1):

1. All CTS diagnostic tests were conducted during or after the first encounter with the orthopedics department.
2. Patients underwent a CTR surgery after a positive CTS diagnosis.
3. Patients underwent a CTR surgery within 90 days of the diagnosis as a means to exclude statistical outliers wherein the delay was not due to additional testing.

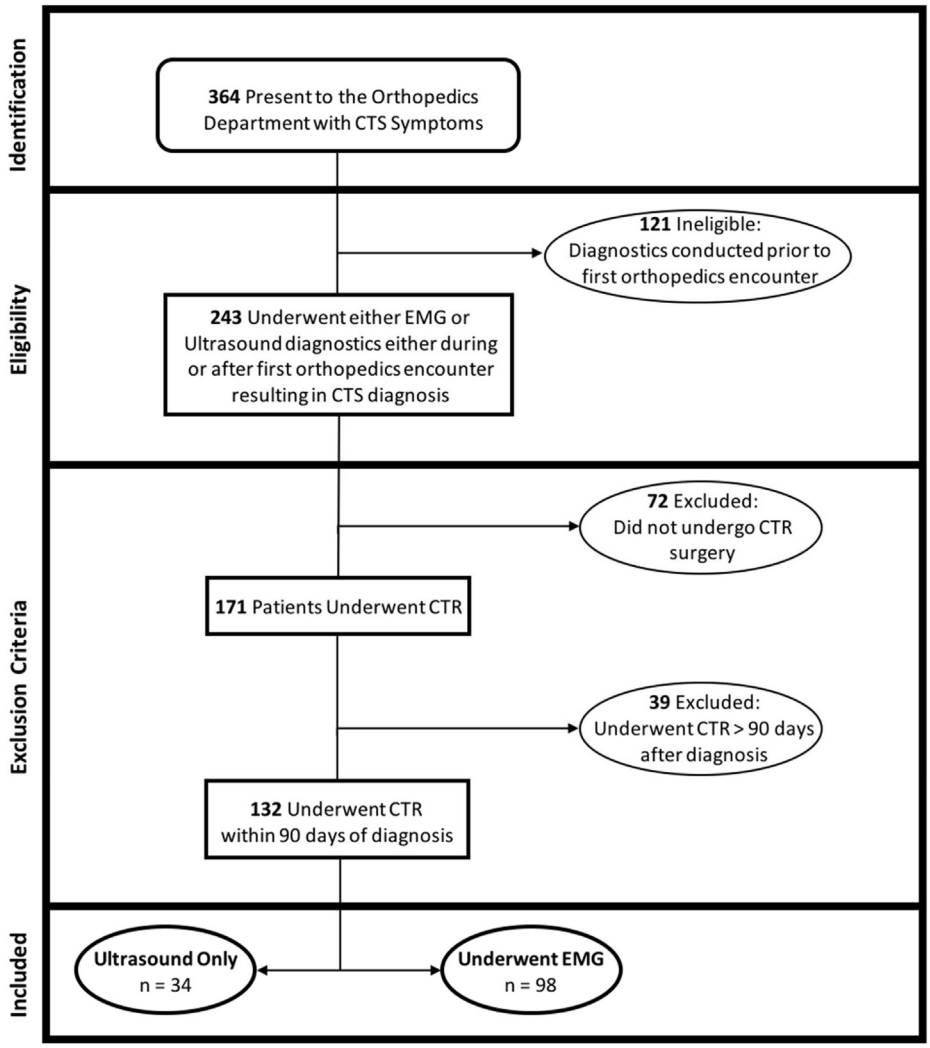

FIGURE 1: A flow diagram illustrates the research criteria considered when extracting a subset of patients from the CTS database.

Descriptive statistics, mean estimates, and 95% CIs were computed for both the US and EMG/NCS diagnostic methods. Student's *t* tests were used to compare the days until CTR surgery and the number of medical visits between the US and EMG/NCS diagnostic groups.

RESULTS

A cohort of 132 participants, consisting of 39 men and 93 women, with a mean age of 56 and 51 years, respectively, was included in the study. Ultrasound was used to confirm diagnosis in 34 patients and EMG/NCS in 98 patients, with similar patient demographics, functional severity, and symptom severity scores, prior to surgery (Table 1). The overall time to surgery for all the participants averaged 41 days, whereas the average number of medical visits, including office visits to the surgeon and EMG/NCS physician, prior to surgery was 2.6. However, when the diagnostic groups were compared, the average time to surgery for the US and EMG/NCS diagnostic groups was 24 and 47 days ($P < .05$), respectively (Fig. 2A). Therefore, patients with CTS confirmed using US underwent CTR approximately 3 weeks earlier than patients with CTS confirmed using EMG/NCS ($P < .05$). For the EMG/NCS group, the average time between the initial CTS visit to the orthopedic clinic and the completion of EMG/NCS diagnostic testing was 18 days, representing 38% of the overall time to surgery (Fig. 3). After subtracting the number of days required to complete EMG/NCS diagnostic testing (18 days) from the overall time to surgery for the EMG/NCS diagnostic group (47 days), the time to surgery for the EMG/NCS diagnostic group was similar to that for the US diagnostic group, 29 and 24

TABLE 1. Baseline Characteristics for All Patients With CTS Who Underwent CTR Surgery Based on Patient Sex

Characteristic	US (n = 34)	EMG (n = 98)
Age (y), mean (SD)	52.3 (12.4)	52.8 (13.5)
Body mass index (kg/m^2), mean (SD)	32.1 (7.0)	33.1 (8.5)
Patient race, number (%)		
Caucasian	25 (73.5)	72 (73.5)
African American	8 (23.5)	24 (24.5)
Asian	0 (0.0)	1 (1.0)
Unknown/not reported	1 (2.9)	1 (1.0)
Boston Carpal Tunnel Questionnaire, mean (SD)		
Functional severity score	2.85 (0.86)	2.52 (0.86)
Symptom severity score	3.27 (0.79)	3.17 (0.74)

days, respectively (Fig. 3). Similarly, the average number of medical visits prior to surgery for the US and EMG/NCS diagnostic groups was 1.2 and 3.1 ($P < 0.05$), respectively (Fig. 2B). Patients with CTS confirmed using US experienced 1.8 fewer medical visits on average than patients with CTS confirmed using EMG/NCS ($P < .05$).

DISCUSSION

Overall, we found that patients who underwent EMG/NCS after their first CTS-related visit had to wait for a longer time for surgery and had an increased number of medical visits prior to surgery than patients who only underwent US. The medical visits largely consisted of additional testing visits related to diagnostic testing and further follow-up visits to the orthopedic provider to review the testing results. A prior analysis showed that US as a first-line test for the diagnosis of CTS is more cost-effective when conducted by a specialist compared with when conducted by a primary care physician.[14] In addition to saving roughly $76 per patient when a surgeon uses US rather than EMG/NCS for CTS diagnosis, the reduction in the number of medical visits can reduce health care spending by an additional $80 per medical visit, determined based on current Medicare reimbursement rates.[14] According to our results, the 1.8 fewer medical visits observed in the US group would have coincided with a $144 reduction in health care spending per patient. Furthermore, using US rather than EMG/NCS for the confirmation of CTS diagnosis will not only help save $220 per patient but also mitigate substantial reductions in surgical delays by several weeks to months.[7] However, the need for any additional diagnostic testing in the majority of CTS cases may be reasonably questioned. If neither EMG/NCS nor US was used as a confirmatory test and the diagnosis simply relied on clinical diagnosis and/or a diagnostic tool, such as the 6-item CTS symptoms scale (CTS-6), it might have reduced the number of medical visits and expedited the time to surgery. Additionally, some physicians may call patients rather than have them return to the office to discuss EMG/NCS results, thus saving an additional office visit and, potentially, the time to surgery. Finally, this study assumed that both EMG/NCS and US are "perfect" tests, without any false negatives or false positives, which is clearly not accurate.

Crasto et al[15] observed a significant increase in US proficiency, with up to 97% correct median nerve measurements after 5 minutes of concise instruction from a fellowship-trained hand surgeon with extensive experience in CTS diagnosis using US. Thus, for CTS cases handled by an experienced surgeon after receiving a brief instruction on US-guided CTS diagnosis, US may result in a shorter time to surgery and reduce the number of medical visits. It is important to recognize that the surgeon performed all the US examinations in this study. If the surgeon had refered the patient to the radiology department or a different provider for the US examination, there would have likely been no savings in terms of medical visits, costs, and time to surgery. Surgeons may also charge for US examinations, which was not done in this study. The senior author considers this part of the office visit and does not charge for it. Furthermore, as mentioned above, there was no control group with which to compare the use of US alone.

A significant limitation identified in this study was the lack of random assignment. The patients were not randomly assigned to a diagnostic method nor were they randomly assigned to 1 of the 2 hand surgeons recruited for this study. When the lack of random selection is considered, the patient sample evaluated in this study may not be generalizable to all patients with symptoms of CTS, and in our case, the decision to use US or EMG/NCS for diagnosis was made based on surgeon preference. Given that all the US diagnostic tests were conducted by surgical specialists, the results do not adequately reflect the use of nonspecialist-conducted US for CTS diagnosis. Specifically, although in our experience, US use does not interrupt the flow of a standard office visit, we did not

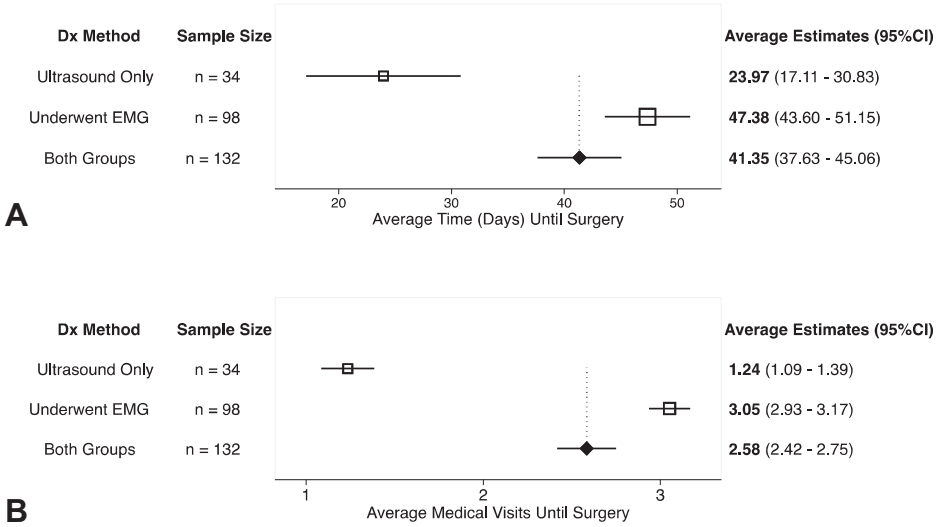

FIGURE 2: A forest plot illustrates the **A** average estimates related to CTS from the date of diagnosis to CTR surgery for days until surgery and **B** number of medical visits. The horizontal lines represent 95% CIs, and the vertical dashed lines denote reference points for the overall cohort's mean estimate. Dx, diagnostic.

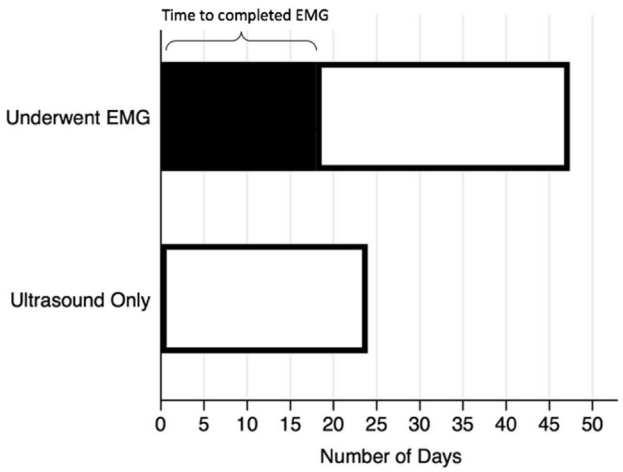

FIGURE 3: A stacked horizontal boxplot demonstrates the average time from initial encounter with the orthopedics department to CTR surgery for both the diagnostic groups.

account for potential challenges and opportunity costs faced by clinicians inexperienced with US. If US takes additional time in the office when performed by a surgeon, that surgeon may not be able to evaluate as many patients, and that might result in decreased productivity. Another limitation is that a prior study showed that performing EMG/NCS was associated with a delay of greater than 90 days.[8] The current study excluded patients who had a delay of greater than 90 days because we assumed that the delay was due to factors other than performing the test. Although the study by Lu et al[8] did not qualitatively determine that the delay of greater than 90 days was due to EMG/NCS testing, it is possible. By excluding these patients, we might have biased our results. However, US would have likely been favored even further if patients with a delay of greater than 90 days were included. Electromyogram and NCS might help obtain some additional information, such as ruling in or out cervical radiculopathy or polyneuropathy. Some use EMG/NCS grading to inform prognosis, although the data on this are conflicting. Finally, this study did not address the use of CTS-6, a validated diagnostic tool used to estimate the probability of CTS based on pertinent history and a physical examination. It is likely that CTS-6 would have had similar results and provided a more cost-effective route for diagnosis; a prior analysis of EMG/NCS testing in patients in whom the pretest probability was determined using CTS-6 found that EMG/NCS does not change that probability.[6]

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