Correlating Ultrasound Echogenicity of the Abductor Pollicis Brevis and Median Nerve Cross-Sectional Area in the Setting Carpal Tunnel Syndrome: A Pilot Study

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ABSTRACT

Introduction: Carpal tunnel syndrome is the most common peripheral entrapment neuropathy, often associated with structural and functional changes in the median nerve and thenar muscles. Neuromuscular ultrasound is increasingly used to complement nerve conduction studies in carpal tunnel syndrome evaluation, yet its potential for assessing muscle integrity remains underexplored. This pilot study examined correlations between median nerve cross-sectional area (MNCSA) and abductor pollicis brevis (APB) muscle characteristics on ultrasound.

Methods: Veterans were enrolled at the Clement J. Zablocki VA Medical Center from July to November 2023. Inclusion criteria were age ≥18 years, carpal tunnel syndrome confirmed by nerve conduction studies, and planned carpal tunnel release. Exclusion criteria included prior carpal tunnel release, upper limb trauma or surgery, hand deformities, peripheral neuropathy, and diabetes. Ultrasound images of the median nerve and APB were obtained. Using Adobe Photoshop, APB echogenicity (grayscale value, black/white ratio) and cross-sectional area in longitudinal and transverse views were calculated and analyzed for correlation with MNCSA.

Results: Ten participants were included. Strong negative correlations were observed between MNCSA and APB cross-sectional area in longitudinal and transverse views (Pearson coefficients, –0.51 and –0.50, respectively). Weak to moderate positive associations were found between MNCSA and APB echogenicity values (0.32 and 0.24, respectively).

Conclusions: APB characteristics on ultrasound, including echogenicity and cross-sectional area, may serve as complementary indicators of carpal tunnel syndrome. Future research should include larger samples, control groups, and assessment of correlations with carpal tunnel syndrome severity on nerve conduction studies.

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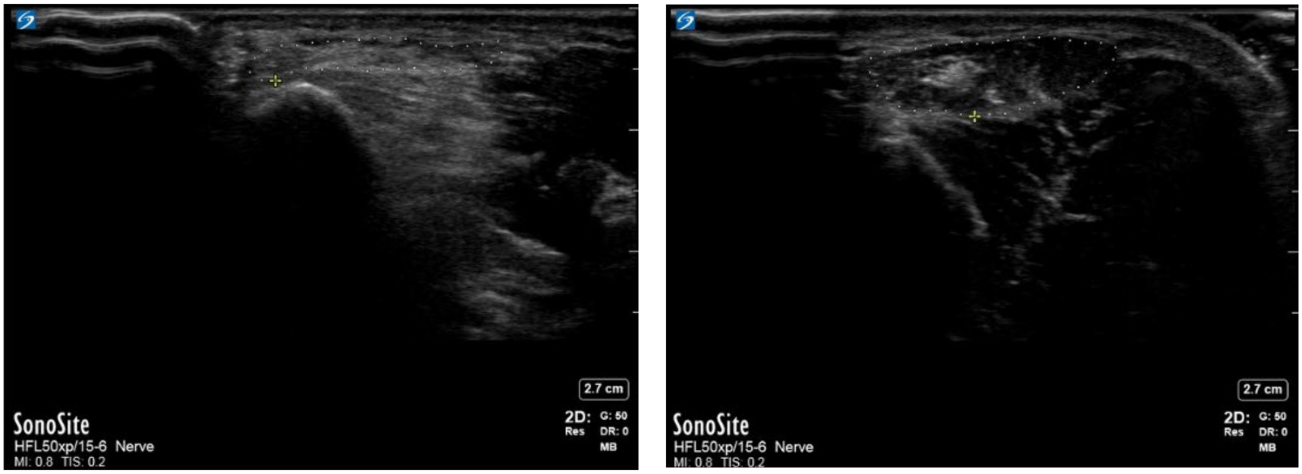
INTRODUCTION

With an estimated incidence of 1 to 5 per 1000 person-years, carpal tunnel syndrome (CTS) is the most common peripheral entrapment mononeuropathy in humans.[1] The condition results from compression of the median nerve at the carpal tunnel.[2] Patients often experience sensory paresthesia, pain, and functional deficits of the affected hand.[1,2] Known risk factors include female sex, diabetes, obesity, pregnancy, hypothyroidism, and multiple environmental factors.[3] Diagnosis is typically made based on clinical history and physical examination, followed by confirmatory nerve conduction studies, the current clinical gold standard.[4]

A growing number of physicians recognize that neuromuscular ultrasound provides a painless, efficient evaluation of the median nerve at the carpal tunnel.[5] Consequently, neuromuscular ultrasound is increasingly being used in conjunction with nerve conduction studies to evaluate for CTS.[5] Commonly cited diagnostic indicators include median nerve cross-sectional area (MNCSA) at the wrist, median nerve vascularity, and median nerve structural changes at the carpal tunnel.[5] Of these, MNCSA demonstrates the best sensitivity and specificity.[6,7] A MNCSA of 10 mm^2 is generally accepted as the upper limit of normal, beyond which CTS may be suspected.[8]

Though less commonly appreciated, neuromuscular ultrasound also enables assessment of muscle health and integrity.[9] In CTS, this information may prfigureovide valuable clinical and diagnostic data. Specifically, echogenicity of thenar muscles increases in

Figure 1. Cross Section of the Abductor Pollicis Brevis Demonstrating Differences in Echotexture Including Hypoechoic Versus Hyperechoic Areas



advanced CTS cases,[10] These changes likely occur due to increased tissue density from neurogenic denervation, producing a brighter ultrasound appearance, referred to as increased echogenicity.[9] Differences in echotexture are shown in Figure 1.

Building on this knowledge, our pilot study investigated potential correlations between abductor pollicis brevis (APB) muscle characteristics on ultrasound and MNCSA in patients with CTS confirmed by nerve conduction studies. This information may improve understanding of CTS pathophysiology and expand the diagnostic applications of neuromuscular ultrasound.

METHODS

This pilot study was conducted at the Clement J. Zablocki Veterans Affairs Medical Center (CJZVA) in Milwaukee, Wisconsin. After institutional review board (IRB) approval, eligible patients were identified through chart review of referrals to Physical Medicine and Rehabilitation, Orthopedic Surgery, and Plastic Surgery for CTS evaluation and management. Inclusion criteria were age >18 years and CTS confirmed by nerve conduction studies. Exclusion criteria were prior carpal tunnel release, upper limb trauma or surgery, hand deformities, peripheral polyneuropathy, and diabetes. Patients meeting inclusion criteria were approached by phone or in person. After informed consent per IRB protocol, patients were enrolled and scheduled for neuromuscular ultrasound evaluation at the CJZVA Translation Research Unit.

All ultrasounds were performed by a board-certified physiatrist with additional qualifications in electrodiagnostic medicine and neuromuscular ultrasound, as recognized by the American Board of Electrodiagnostic Medicine. Images were obtained using a Sonosite X-porte machine with a 5-12 Mhz linear probe. All images were deidentified and saved to an IRB-approved encrypted USB drive, stored securely at CJZVA per protocol.

Table. Calculated Pearson Coefficients Between Median Nerve Cross-Sectional Area and Abductor Pollicis Muscle Brevis (APB) Echogenicity Values (EV) and Echogenicity Ratios (ER)

Muscle	Pearson Coefficient
APB Longitudinal EV	0.32
APB Longitudinal ER	-0.11
APB Transverse EV	0.24
APB Transverse ER	-0.07

Subjects were examined in a seated position with the wrist supinated and elbow fully extended. Using the linear probe, the median nerve was identified in cross-section immediately ventral to the pronator quadratus muscle, then traced distally to the carpal tunnel entrance, identified by the scaphoid and pisiform bones. Still images of the median nerve were captured in transverse and longitudinal views, and the MNCSA in the transverse view was calculated using Sonosite software. The probe was then moved to the thenar eminence, where APB was identified via anatomic landmarks. APB was selected for analysis due to its limited ulnar nerve innervation compared with other thenar muscles. Still images of APB were captured in transverse and longitudinal views.

Image and Data Analysis

APB echogenicity was analyzed using Adobe Photoshop (Adobe Inc). The lasso tool was used to isolate the APB from surrounding structures. As shown in Figure 2, echogenicity was assessed by calculating black and white pixels and mean brightness on a scale of zero (black) to 255 (white). Mean brightness was obtained from the histogram function and termed echogenicity value. Ratios of black pixels to total were calculated and termed echogenicity ratio. Both metrics were calculated for each subject. APB cross-sectional area was also measured in longitudinal and transverse views.

Statistical analysis was completed using Pearson's coefficient due to the paired nature of the data. Normal distribution was confirmed with the Shapiro-Wilk test. Pearson coefficients were calculated between MNCSA and APB echogenicity ratio/value, and MNCSA and APB cross-sectional area. Power analysis was not performed due to limited sample size.

RESULTS

After inclusion criteria were met, 13 patients were enrolled; 3 did not attend the initial visit and were excluded. Thus, 10 patients were analyzed.

The mean MNCSA was 17 mm^2. Strong negative correlations were found between MNCSA and APB cross-sectional area in longitudinal and transverse views (Pearson coefficients, -0.51 and -0.50, respectively). Weak to moderate associations were found between MNCSA and APB echogenicity value in longitudinal and transverse views (Pearson coefficients, 0.32 and 0.24, respectively). All Pearson coefficients are shown in the Table.

DISCUSSION

This pilot study sought to identify associations between MNCSA and APB muscle changes on ultrasound in patients with carpal tunnel syndrome. Although limited by sample size, several important findings emerged. Specifically, the data demonstrate correlations between MNCSA and APB echogenicity and cross-sectional area.

The strong inverse relationship identified between APB cross-sectional area and MNCSA aligns with previous reports of muscular atrophy on ultrasound in CTS.[10] Although CTS severity was not measured, prior studies have correlated MNCSA with severity; thus, APB cross-sectional area may serve as a useful metric for gauging severity. Awareness of this potential association is important for clinicians using neuromuscular ultrasound to evaluate CTS.

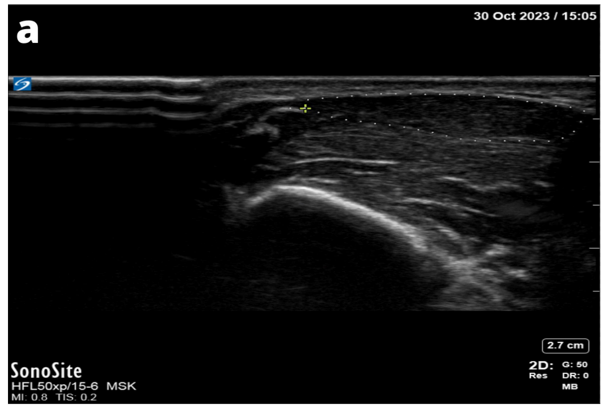
Associations between MNCSA and APB echogenicity ratio/value, though weaker, confirm previously described ultrasound findings of neurogenic denervation. Specifically, increased muscle echogenicity reflects intramuscular fibrosis and fatty infiltration in CTS. While routine calculation of these values may be impractical, recognition of muscular changes on ultrasound remains critical for clinicians performing neuromuscular ultrasound.

Study limitations include the small sample size (n = 10), recruitment from a veteran population (limiting generalizability), and potential variability in ultrasound technique, intraoperator reliability, and patient comorbidities. The absence of a control group without CTS further limits comparisons.

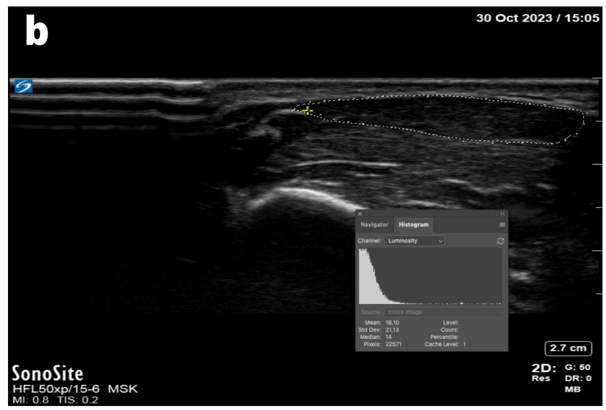
CONCLUSIONS

The findings of this study support the use of neuromuscular ultrasound to enhance understanding of carpal tunnel syndrome pathophysiology, particularly regarding abductor pollicis brevis muscle changes. More specifically, APB evaluation may complement more established CTS diagnostic methods. Future research should include a larger sample size, addition of a control group, and exploration of correlations with CTS severity on nerve conduction studies.

Figure 2. Calculating Echogenicity Values and Ratios of the Abductor Pollicis Brevis (ABP) Muscle in Short Axis Utilizing Adobe Photoshop



A. Image of the APB exported directly from ultrasound.



B. Lasso tool on Photoshop selecting the muscle and the histogram feature displaying values.

C. Selection of only black pixels within the muscle and the histogram feature displaying values.

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