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Ultrasonographic Evaluation of the Abductor Pollicis Brevis Muscle in Patients with Carpal Tunnel Syndrome Classified According to EMG Findings

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What is known on this subject?

Ultrasonography is commonly used in carpal tunnel syndrome (CTS), mainly to assess median nerve enlargement. Electrophysiological studies are the standard method for determining disease severity and motor involvement. Although thenar muscle atrophy may occur in CTS, quantitative ultrasonographic evaluation of the abductor pollicis brevis across different severity stages has been insufficiently investigated.

What this study adds?

Quantitative ultrasonographic parameters of the abductor pollicis brevis muscle decrease proportionally with disease severity and correlate with electrophysiological findings.

ABSTRACT

Objective: To evaluate the relationship between quantitative muscle ultrasound parameters of the abductor pollicis brevis (APB) and disease severity in carpal tunnel syndrome (CTS).

Material and Methods: This cross-sectional, comparative clinical study included 76 patients. Participants were stratified into four electromyography (EMG)-based categories (EMG-normal, mild, moderate, and severe CTS). In the transverse ultrasound images of the APB, we measured cross sectional area and thickness of the muscle. Differences in muscle thickness, cross-sectional area (CSA), and pinch strength among four groups were analyzed.

Results: The CSA of the APB muscle decreases with increasing disease severity. Thickness and pinch strength are significantly decreased in severe CTS. There is a significant negative correlation between the CSA of the APB muscle and the distal motor latency of the median nerve.

Conclusion: Quantitative ultrasound parameters of the APB muscle are useful for evaluating disease severity in CTS.

Keywords: Abductor pollicis brevis, carpal tunnel syndrome, electromyography, pinch grip strength, thenar muscle

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Introduction

Carpal tunnel syndrome (CTS), the most common entrapment neuropathy, results from compression of the median nerve within the carpal tunnel, a confined fibro-osseous canal at the wrist (1). CTS occurs considerably more frequently in women than in men, with epidemiological data indicating an approximately threefold higher prevalence among women. Moreover, bilateral involvement is observed in a substantial proportion of affected individuals (2). As the disease progresses, motor fiber involvement may become clinically apparent, leading to reduced strength during thumb abduction and opposition. In the absence of timely intervention, ongoing denervation can ultimately result in atrophic changes in the median nerve–innervated hand muscles.

In most cases, a careful medical history combined with physical examination is sufficient for establishing the diagnosis of CTS. When clinical findings are equivocal, electrophysiological evaluation plays an important role in grading disease severity and guiding decisions regarding surgical management (3). Electromyography (EMG) and nerve conduction studies (NCS) provide sensitive information on both demyelinating processes and axonal injury or recovery. Needle EMG of the thenar muscles may be particularly useful for identifying early axonal involvement in patients with distal motor latency (DML) values exceeding 4.9 ms (4). Nevertheless, needle EMG is an invasive technique that can be uncomfortable for patients and, in certain situations, may be technically challenging, because obtaining reliable results depends on adequate patient cooperation.

Ultrasonography (US) represents a practical imaging modality owing to its non-invasive nature, broad availability, and ease of use in routine clinical settings. It is generally well tolerated by patients, does not involve significant adverse effects, and is considered a safe technique with no major contraindications (5).

In CTS, sustained compression within the carpal tunnel may result in proximal nerve swelling due to edema, while accompanying fibrotic changes contribute to structural enlargement of the median nerve (6). On transverse ultrasonographic evaluation, these pathological alterations are commonly reflected by an increase in the nerve's cross-sectional area (CSA). Edema-related changes may also cause the nerve to appear more hypoechoic, with reduced clarity of fascicular architecture due to loss of perineurial definition (7). Previous studies have shown that median nerve CSA values in healthy populations exhibit a wide normal range (reported between 6.1 and 10.4 mm^2), which has hindered the establishment of a universal diagnostic cut-off (8,9). To overcome this variability, Klauser et al. (10) proposed comparing CSA measurements at the wrist and forearm levels, reporting that a difference exceeding 2 mm^2 provides excellent diagnostic accuracy. In line with this approach, other investigations have suggested that ratios incorporating proximal median nerve measurements may further enhance diagnostic sensitivity (11,12). Additionally, a reduction in the forearm median nerve CSA has been associated with axonal loss in patients with CTS (13).

Beyond neural changes, sustained median nerve compression in CTS leads to denervation-related structural alterations in median-innervated muscles, most prominently affecting the abductor pollicis brevis (APB). Progressive motor fiber involvement may result in reductions in muscle thickness, CSA, and functional strength, reflecting disease severity at the muscular level. Despite the clinical relevance of thenar muscle involvement in CTS, ultrasonographic evaluation of APB muscle morphology has received considerably less attention than median nerve assessment, and available data remain limited, particularly across the full spectrum of CTS severity.

Although ultrasonographic evaluation of the median nerve is a well-established and sensitive method in CTS, most US-based studies have focused on structural alterations of the nerve (14,15). By comparison, investigations examining muscular alterations within the territory innervated by the median nerve in focal neuropathies, such as CTS, remain relatively limited (16,17). Notably, the study by Lee et al. (17) was restricted to patients with minimal, mild, and moderate disease severity and did not include individuals categorized as severe or extreme CTS based on the Padua criteria. While ultrasonographic evaluation of the median nerve is well established, data regarding structural changes in median-innervated muscles—particularly the APB—remain limited, especially across the full spectrum of CTS severity. Against this background, the present study aimed to assess, across different stages of CTS severity, APB muscle thickness and CSA and pinch grip strength, and to examine the relationships between these parameters and electrophysiological findings.

Material and Methods

This study was conducted at İstanbul Physical Medicine and Rehabilitation Training and Research Hospital. Patients provisionally diagnosed with CTS who voluntarily consented

to participate in the study were enrolled. Each participant received detailed information about the study procedures and provided signed consent before enrollment. This study was derived from a thesis project. Eligible participants included women between 18 and 75 years of age who had undergone NCS and/or EMG testing confirming a CTS diagnosis. Individuals with systemic or neurological disorders that could affect peripheral nerves—such as diabetes, malignancies, central nervous system diseases (e.g., multiple sclerosis, motor neuron disorders), prior wrist trauma or surgery, radiculopathy, or other neuropathies—were excluded.

This cross-sectional clinical study involved 76 participants. Collected data included demographic characteristics (e.g., age, height, weight, and body mass index), as well as information on hand dominance. Sample size calculation was performed a priori based on previously published APB muscle thickness data, yielding an effect size (Cohen's d) of 1.33. An unpaired t-test (α: 0.05, power: 0.95) indicated a required sample size of 13 participants per group, calculated using G*Power (17).

Ultrasound assessments were performed by a single investigator blinded to both clinical presentation and EMG results, using a diagnostic system (Esaote MyLab60) with a 7–12 MHz linear transducer. APB muscle thickness and CSA were measured bilaterally while participants sat in a relaxed position with neutral shoulder alignment, 90° of elbow flexion, forearm supination, neutral wrist alignment, and fingers fully extended. Muscle ultrasound assessments followed the standardized method outlined by Simon et al. (18) the probe was aligned perpendicularly over the midpoint of the first metacarpal bone, following its longitudinal orientation.

To reduce probe pressure during scanning, coupling gel was applied generously. APB thickness was quantified by measuring the distance across the muscle at its thickest section using the device's built-in function. CSA was determined by tracing the hyperechoic fascial border surrounding the muscle using the system's trace area tool. Intra-rater reliability was assessed by repeating APB thickness and CSA measurements in a randomly selected subset of 10 participants (20 hands) and quantified using the intraclass correlation coefficient (ICC).

Pinch grip strength was assessed on the same day as the US examination, using a Saehan SH50005 hydraulic pinch gauge (19). For each hand, three tip-to-tip pinch measurements were obtained at one-minute intervals while participants were seated.

Electrophysiological evaluations were carried out in a quiet, moderately lit environment maintained at 22–24 °C, with participants in the supine position, using a Dantec Keypoint 3-channel EMG system. Recordings included motor and sensory NCS parameters of the median and ulnar nerves (3).

Motor and sensory NCSs of both the median and ulnar nerves were performed in all participants. Median sensory NCS was obtained using a ring electrode placed on the second digit, with antidromic stimulation applied at the wrist to record latency, amplitude, and conduction velocity. Median motor NCS was conducted using surface electrodes positioned over the APB, with stimulation delivered at the wrist and the antecubital fossa to measure compound muscle action potential (CMAP) amplitude, latency, and conduction velocity. Needle EMG was performed when clinically indicated. Ulnar sensory NCS was recorded from the fifth digit using a ring electrode and antidromic wrist stimulation, while ulnar motor NCS was obtained from the adductor digiti minimi using surface electrodes, with stimulation applied at the wrist and above the elbow to evaluate CMAP parameters. In cases with normal routine findings, a fourth-finger median-to-ulnar sensory comparison study was performed using ring electrodes with equal-distance stimulation of both nerves. A peak latency difference greater than 0.5 ms was considered indicative of CTS.

Based on EMG findings, patients were classified using the severity grading system proposed by Sucher (20) in 2013. The grading criteria were defined as follows:

Mild CTS: Prolongation of sensory or mixed nerve latency with preserved DML and amplitudes, and no evidence of conduction block or abnormal findings on needle EMG. In some cases, comparative testing may reveal relatively prolonged sensory latency of the median nerve, even when absolute latency values are within normal limits.

Moderate CTS: Findings consistent with mild CTS accompanied by prolonged DML and a mild, non-significant reduction in recorded amplitudes.

Severe CTS: Absence of sensory nerve action potential (SNAP) or markedly prolonged sensory latency associated with reduced SNAP amplitude, or absent CMAP together with markedly prolonged DML and low motor amplitude. Alternatively, severe CTS may be characterized by abnormal needle EMG findings, including frequent fibrillation potentials, a reduced interference pattern during maximal voluntary contraction, and changes in motor unit action potentials.

In addition to the defined CTS severity groups, participants who had clinical symptoms suggestive of CTS but had no abnormal findings on NCS/EMG were assigned to the "EMG-normal" group. These individuals were not considered healthy controls.

All clinical assessment tools and quantitative measurement techniques applied in this study were derived from previously validated methods and were accessible for academic use. The ultrasonographic protocol was performed in accordance with Simon et al. (18); CTS severity classification was based on the system described by Sucher (20); and pinch grip strength was measured using a Saehan hydraulic pinch gauge (Model SH50005, Saehan Corporation, Korea) (19). No special authorization or licensing was required for the use of these instruments.

Written informed consent was obtained from all participants following a detailed explanation of the study objectives and procedures. Ethical approval was granted by the Bakırköy Dr. Sadi Konuk Training and Research Hospital Ethics Committee (decision number: 2019-02-17, date: 21.01.2019).

Statistical Analysis

Statistical analyses were performed using MedCalc® version 20.113 (Ostend, Belgium). The normality of continuous variables was assessed using the Shapiro–Wilk test. Normally distributed data are presented as mean ± standard deviation; non-normally distributed data are presented as median (interquartile range). Categorical variables are presented as frequencies and percentages. Because measurements could be obtained from both hands of the same participant, the primary analysis was prespecified to include one hand per participant (the more severely affected hand according to EMG findings; if severity was equal, the dominant hand was selected) to avoid violating the assumption of independence. Group comparisons across EMG-defined categories were performed using one-way analysis of variance with Tukey post-hoc testing for parametric variables and the Kruskal–Wallis test followed by Bonferroni-adjusted Mann–Whitney U tests for non-parametric variables. Associations between ultrasonographic parameters, electrophysiological findings, and pinch strength were evaluated using Spearman correlation coefficients. A two-sided p value was considered statistically significant.

Results

Seventy-six patients were included in the study. Patient demographic data are presented in Table 1.

We evaluated 152 hands from 76 patients. According to EMG results, 43 hands were classified as normal, 54 as mild CTS, 29 as moderate CTS, and 26 as severe CTS. The statistical analysis of the demographic data is presented in Table 1.

The comparison of dominant- vs. non-dominant-hand distributions did not reveal statistically significant differences among groups (p>0.05).

Table 1. Demographic data

		Normal (n=43)	Mild CTS (n=54)	Modarate CTS (n=29)	Severe CTS (n=26)	p
		45 (11)	52 (10)	48 (12)	49 (15)	
Age	p^m	Normal–mild <0.001	Normal–severe 0.006	Mild–severe 0.719		$<0.001^K$
		Normal–modarate 0.013	Mild–modarate 0.198	Modarate–severe 0.413		
		27.55±4.7	30.69±4.3	30.07±5.4	31.74±2.8	
BMI	p**	Normal–mild 0.004	Normal–severe 0.001	Mild–severe 0.761		0.001*
		Normal–modarate 0.093	Mild–modarate 0.060	Modarate–severe 0.512		
		3 (4)	3 (9)	5 (6)	4.5 (5)	
Disease duration (years)	p^m	Normal–mild 0.464	Normal–severe 0.097	Mild–severe 0.358		0.042^K
		Normal–modarate 0.005	Mild–modarate 0.060	Modarate–severe 0.276		
Smoking (Yes/No)		6 (14%)/37 (86%)	22 (40.7%)/32 (59.3%)	12 (41.4%)/17 (58.6%)	4 (26%)/22 (84.6%)	0.004^{X^2}
Pack year		0 (0)	0 (10)	0 (8)	0 (0)	
Not working (Housewife)		31 (72.1%)	43 (79.6%)	23 (79.3%)	22 (84.6%)	
Job Worker		8 (18.6%)	9 (16.7%)	5 (17.2%)	4 (15.4%)	0.690^{X^2}
Retired		4 (9.3%)	2 (3.7%)	1 (3.4%)	0 (0%)	

Median (interquartile range), mean ± standard deviation, distribution of categorical variables n (%)

*^{K}: Kruskal–Wallis test, ^{m}: Post-hoc analysis Mann–Whitney U test Bonferoni correction applied, $^{X^2}$: Pearson chi-square test, *One way analysis of variance test, **Post-hoc analysis Tukey test*

BMI: Body mass index, CTS: Carpal tunnel syndrome

When evaluating EMG parameters, notable differences were identified across groups in median sensory latency, sensory conduction velocity and amplitude, and in median motor latency. In contrast, no significant between-group differences were found in median motor nerve conduction velocity. The findings on EMG and hand dominance are presented in Table 2.

Between-group analyses of APB muscle CSA demonstrated statistically significant differences ($p<0.001$). While no meaningful differences were found when comparing the normal group with the mild CTS group or the mild CTS group with the moderate CTS group, significant differences emerged between the normal and moderate CTS groups. Moreover, the severe CTS group differed significantly from all other groups ($p<0.05$; $p<0.001$). Statistical analysis of pinch grip strength using the Kruskal–Wallis test indicated overall significant group differences ($p<0.001$). Subsequent post-hoc evaluations revealed no notable variation between the normal and mild CTS groups, nor between the mild and moderate CTS groups. Nevertheless, the severe CTS group exhibited values that were significantly different from those of all other classifications, including the normal and moderate CTS groups ($p<0.001$), as outlined in Table 3.

Correlation analyses involving quantitative ultrasonographic parameters, pinch grip strength, and EMG findings are detailed in Table 4. Associations were not consistently observed within individual severity strata, which may reflect limited sample sizes within subgroups; however, when CTS cases were analyzed together using the prespecified one-hand dataset, APB CSA showed associations with electrophysiological parameters. However, when the data from all CTS patients were pooled, the CSA of the APB muscle showed significant associations with both sensory and motor electrophysiological parameters of the median nerve ($p<0.01$). Specifically, larger APB CSA values were associated with shorter latencies and higher amplitudes and conduction velocities. A significant negative correlation was observed between APB muscle CSA and median nerve DML (Figure 1). Although APB muscle thickness was also associated with certain sensory parameters, no significant relationships were noted with motor conduction velocity or motor amplitude. A moderate positive correlation was identified between APB muscle CSA and its thickness among CTS patients. While no meaningful association was found between pinch-grip strength and EMG measures in subgroup analyses, combined CTS data demonstrated moderate correlations with sensory

Table 2. Distribution of dominant/non-domiant hands into groups and EMG data

		Normal (n=43)	Mild CTS (n=54)	Modarate CTS (n=29)	Severe CTS (n=26)	p
Dominant/non-dominant hand		18 (41.9%)/25 (%58.1)	30 (55.6%)/24 (44.4%)	16 (55.2%)/13 (44.8%)	12 (46.2%)/14 (53.8%)	0.518$^{x^2}$
		2.92 (0.4)	3.35 (0.4)	4.12 (0.8)	5.50 (1.6)	
Median sensory latency	p^m	Normal–mild **<0.001**	Normal–severe **<0.001**	Mild–severe **<0.001**		**<0.001^K**
		Normal–modarate **<0.001**	Mild–modarate <**0.001**	Modarate–severe <**0.001**		
		41.20 (28.1)	30.00 (15.3)	18.80(8.9)	6.13 (11.6)	
Median sensory amplitude	p^m	Normal–mild **<0.001**	Normal–severe **<0.001**	Mild–severe **<0.001**		**<0.001^K**
		Normal–modarate **<0.001**	Mild–modarate **<0.001**	Modarate–severe **<0.001**		
		61.30 (8.9)	47.15 (8.5)	38.80 (8.9)	29.15 (33.1)	
Median sensory conduction velocities	p^m	Normal–mild <**0.001**	Normal–severe <**0.001**	Mild–severe **<0.001**		**<0.001^K**
		Normal–modarate **<0.001**	Mild–modarate **<0.001**	Modarate–severe **<0.001**		
		2.96 (0.6)	3.63 (0.4)	4.50 (0.5)	6.19 (1.8)	
Median motor latency	p^m	Normal–mild **<0.001**	Normal–severe **<0.001**	Mild–severe **<0.001**		**<0.001^K**
		Normal–modarate **<0.001**	Mild–modarate <**0.001**	Modarate–severe **<0.001**		
		10.20 (7.3)	9.61 (6.5)	9.40 (6.1)	3.45 (1.9)	
Median motor amplitude	p^m	Normal–mild 0.343	Normal–severe **<0.001**	Mild–severe **<0.001**		**<0.001^K**
		Normal–modarate 0.338	Mild–modarate 0.920	Modarate–severe **<0.001**		
		57.50 (6.3)	54.85 (7.2)	56.20 (5.2)	55.40 (8.2)	
Median motor conduction velocities	p^m	Normal–mild 0.141	Normal–severe 0.087	Mild–severe 0.517		0.257^K
		Normal–modarate 0.364	Mild–modarate 0.442	Modarate–severe 0.284		

Distribution of categorical variables n (%), median (interquartile range)

^{x2}: Pearson chi-square test, ^{K}: Kruskal–Wallis test, ^{m}: Post-hoc analysis Mann–Whitney U test Bonferoni correction applied

EMG: Electromyography, CTS: Carpal tunnel syndrome

and motor latencies and amplitudes of the median nerve (p<0.01). No correlation between APB muscle CSA and thickness was observed in the control group; this relationship became progressively stronger with increasing CTS severity.

To assess agreement of ultrasonographic measurements, intra-observer reliability ICC was re-evaluated in 10 patients (20 hands). The intra-observer reliability values are presented in Table 5. The reproducibility of the measurements was very high (p<0.001).

Table 3. Comparison of abductor pollicis brevis muscle thickness and cross-sectional area and pinch grip strength between groups

		Normal (n=43)	Mild KTS (n=54)	Modarate CTS (n=29)	Severe CTS (n=26)	p
		120.26±13.1	111.61±15.6	90.66±12.1	58.27±13.3	
APB cross-sectional area	p**	Normal–mild **0.015**	Normal–severe **<0.001**	Mild–severe **<0.001**		
		Normal–modarate **<0.001**	Mild–modarate **<0.001**	Modarate–severe **<0.001**		**<0.001***
		5.09±0.6	4.77±0.7	4.47±0.8	3.84±0.9	
APB thickness	p**	Normal–mild 0.148	Normal–severe **<0.001**	Mild–severe **<0.001**		
		Normal–modarate **0.004**	Mild–modarate 0.314	Modarate–severe **0.011**		**<0.001***
		3 (0.5)	2.66 (0.5)	2.5 (0.8)	1.6 (0.4)	
Pinch grip	p[m]	Normal–mild 0.010	Normal–severe **<0.001**	Mild–severe **<0.001**		
		Normal–modarate **<0.001**	Mild–modarate 0.042	Modarate–severe **<0.001**		**<0.001**[K]

Mean ± standard deviation, median (interquartile range)

**One way analysis of variance test, **Post-hoc analysis Tukey test, [K]: Kruskal–Wallis test, [m]: Post-hoc analysis Mann–Whitney U test Bonferoni correction applied*

APB: Abductor pollicis brevis

Table 4. Correlation of APB muscle thickness and cross-sectional surface area and pinch grip strength with EMG data

			Median sensory			Median motor		
	APB CSA	APB thickness	Latency	Amplitude	Conduction velocities	Latency	Amplitude	Conduction velocities
Normal grup (n=43)								
APB CSA		0.065	0.095	-0.254	0.018	-0.088	0.120	0.003
APB thickness	0.065		0.086	0.127	0.011	**0.334***	-0.227	0.174
Pinch grip			0.215	-0.129	0.071	0.174	-0.242	-0.027
Mild CTS (n= 54)								
APB CSA		0.408**	0.093	0.047	-0.102	-0.085	0.193	0.013
APB thickness	0.408**		0.210	-0.089	-0.078	0.195	-0.117	-0.011
Pinch grip			0.073	-0.187	-0.027	-0.037	0.071	-0.158
Modarate CTS (n= 29)								
APB CSA		0.386*	0.012	0.161	0.121	0.088	0.081	0.126
APB thickness	0.386*		0.002	-0.116	-0.045	0.077	-0.108	-0.052
Pinch grip			0.143	0.014	0.020	0.343	0.233	-0.065
Severe CTS (n=26)								
APB CSA		0.763**	-0.096	0.152	0.070	-0.257	0.297	0.189
APB thickness	0.763**		-0.183	0.177	0.154	**-0.458***	0.095	0.039
Pinch grip			0.039	0.332	-0.077	-0.035	0.046	0.008
CTS group (n=109)								
APB CSA		0.544**	-0.632**	0.662**	0.648**	-0.720**	0.545**	0.056
APB thickness	0.544**		-0.254**	0.266**	0.274**	**-0.307****	0.166	-0.017
Pinch grip			-0.441**	0.470**	0.491**	-0.503**	0.478**	-0.010

**p value <0.05, **p value <0.01, Spearman's rho coefficients are given*

CSA: Cross-sectional area, CTS: Carpal tunnel syndrom, APB: Abductor pollicis brevis

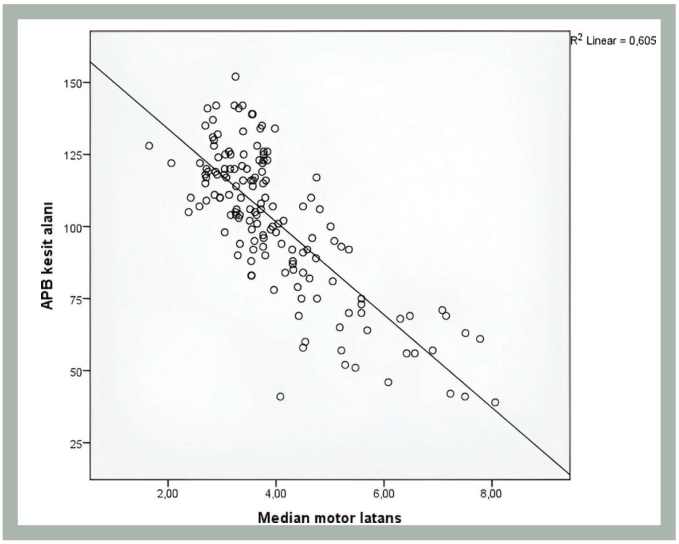

Figure 1. Correlation between APB muscle APB and median nerve DML

APB: Abductor pollicis brevis, DML: Distal motor latency

Table 5. Intra-observer reliability analysis

	ICC	95% confidence interval Lower bound	Upper bound	p
APB thickness	0.981	0.952	0.992	**<0.001**
APB cross-sectional area	0.988	0.969	0.995	**<0.001**

ICC: Intraclass correlation coefficient, APB: Abductor pollicis brevis

Discussion

This study aimed to compare ultrasonographic measurements across CTS severity groups classified by EMG findings and to examine their associations with electrophysiological parameters. Significant differences in APB muscle thickness and CSA were observed among severity levels. Intergroup variations were also evident in pinch grip strength. A notable negative correlation was identified between APB muscle CSA and median nerve DML. These findings suggest that APB muscle thickness and CSA may reflect motor involvement and EMG-defined disease severity in CTS, providing complementary structural information alongside electrophysiological assessment.

EMG is important for establishing the diagnosis of CTS and for determining the severity of the disease and, accordingly, the appropriate treatment. Nevertheless, it is often uncomfortable for patients and may be poorly tolerated by individuals with low pain thresholds or CTS-related neuropathic pain. In addition, EMG may delay definitive management in patients requiring surgical intervention and increase healthcare costs (21). Furthermore, while EMG reflects the functional severity of CTS, it provides limited information regarding underlying anatomical causes. In a retrospective analysis, Iyer evaluated 4,800 patients who were referred for EMG with a preliminary CTS diagnosis over a five-year period (22). Among those classified as having severe CTS based on EMG findings, subsequent median nerve US identified idiopathic CTS in most cases, whereas a small subset had specific structural pathologies, including lunate subluxation, schwannoma, lipofibromatous hamartoma, and trauma-related neuroma.

Musculoskeletal US is used to reveal changes in muscle thickness and volume in pathological conditions. Several recent publications have explored ultrasound applications in diagnosing CTS; however, these works have largely focused on identifying increases in the median CSA (23). In neurogenic diseases, muscles undergo structural changes, including atrophy. These changes can be displayed or even quantified using US (24). In addition to muscle thickness and CSA, echo intensity can be measured using US; however, this measurement was not used in our study because it varies from device to device and is less reproducible than measurements of muscle thickness and CSA (25,26). Additionally, previous studies have reported that patient sex significantly affects quantitative US measurements of muscles; therefore, only female participants were recruited in this study to reduce inter-individual variability (27,28).

In a 2016 study, Lee et al. (17) compared quantitative US findings between patients with CTS and healthy controls, and reported significantly reduced APB muscle thickness and CSA in the CTS group. Likewise, Simon et al. (26) evaluated quantitative US measurements of several muscles in patients with amyotrophic lateral sclerosis, CTS, and ulnar neuropathy and observed a decrease in APB muscle thickness compared with that of healthy individuals, with greater thinning accompanying increasing denervation severity. Consistent with these observations, our study also demonstrated a reduction in APB muscle thickness in CTS. Although Simon et al. (26) did not assess APB muscle CSA, Lee et al. (17) evaluated it, and our findings agreed with theirs. In the present study, APB muscle CSA was significantly lower in the CTS group than in the normal group, with a progressive reduction corresponding to increasing disease severity.

The study by Lee et al. (17), which examined the association between APB muscle CSA, thickness, and EMG findings, reported a significant positive correlation of APB echo intensity with both median sensory onset latency and DML, but found no association of APB muscle thickness or

CSA with EMG parameters. These findings differ from ours and may be explained by methodological differences. First, Lee et al. (17) applied a different severity classification and included predominantly mild CTS cases [78% (28 of 36 hands)], with the remaining cases classified as moderate CTS [22% (8 of 36 hands)]; no cases of severe CTS were included. Consistent with this, intragroup analyses in our study also showed no correlation between APB muscle CSA or thickness and EMG findings in mild and moderate CTS; however, when all CTS cases were analyzed together, significant associations emerged. Second, the smaller sample size in the study by Lee et al. (17) may have limited the study's statistical power to detect such relationships. In contrast, our study evaluated patients across the full spectrum of CTS severity, including severe cases, allowing a more comprehensive assessment of how disease severity affects quantitative US parameters.

Weakness of the opponens pollicis and APB muscles, which may be caused by CTS, can be compensated for by other synergist muscles, and thus CTS may not have a significant effect on gross grip strength and lateral grip strength. However, tip-to-tip pinch strength is mostly generated by the thenar muscles and is a more useful measurement in demonstrating motor involvement associated with CTS (19). In our study, intergroup comparison of pinch-grip strength showed a significant decrease in individuals with severe CTS compared with those in milder categories. The results of our study are consistent with previous studies (28,29). Atalay et al. (29) evaluated a cohort of 99 individuals, divided participants based on EMG-defined severity levels: mild, moderate, and severe, and identified notable differences between the severe CTS subgroup and the others in terms of tip pinch strength. Keskin et al. (28) ssessed the hands of 106 individuals with CTS categorized into three EMG-based subgroups. They found that patients with advanced CTS had significantly decreased pinch grip strength compared with the moderate and mild CTS groups. Moreover, they reported that pinch grip strength was moderately correlated with DML, and that grip strength decreased with increasing motor latency.

US is widely used in the evaluation of CTS-related structural changes (30). However, publications on the use of ultrasound for diagnostic purposes in CTS have primarily focused on measuring CSA in the median nerve. ur results indicate that APB muscle changes associated with median nerve entrapment can be detected by ultrasound and appear to relate to EMG-defined severity; Lee et al. (17) suggested that APB muscle CSA and thickness could be used in the diagnosis of CTS; however, they did not propose any cut off value. Ultrasonographic changes in the APB muscle appear to parallel electrophysiologically defined motor involvement in CTS. These findings should be interpreted as descriptive associations rather than indicators of diagnostic accuracy.

Study Limitations

This study has a number of limitations. First, since our study only included female patients, the results cannot be generalized to the whole population. Patients included in the study and classified as normal were referred from the outpatient clinic to the electrophysiology laboratory, and thus were already symptomatic. Although EMG results were negative in these patients, EMG and NCS may be negative in some patients with CTS. Because patients were grouped by disease severity, demographic homogeneity between groups could not be achieved.

Conclusion

The thickness and CSA of the APB muscle decline in parallel with increasing CTS severity. Similarly, pinch grip strength diminishes as the condition progresses. Among individuals diagnosed with CTS, both APB muscle thickness and CSA demonstrated meaningful associations with sensory and motor conduction parameters, including latency, amplitude, and velocity, as assessed via NCS.

In summary, this study indicates that quantitative ultrasonographic evaluation of the APB muscle can serve as an indicator of CTS-related thenar muscle alterations, reflecting disease severity.

Ethics

Ethics Committee Approval: Ethical approval was granted by the Bakırköy Dr. Sadi Konuk Training and Research Hospital Ethics Committee (decision number: 2019-02-17, date: 21.01.2019).

Informed Consent: Written informed consent was obtained from all participants following a detailed explanation of the study objectives and procedures.

Footnotes

Authorship Contributions

Concept: İ.A., B.H., K.Ö., Design: B.H., K.Ö., Data Collection or Processing: İ.A., B.H., Analysis or Interpretation: İ.A., M.D., B.H., K.Ö., Literature Search: İ.A., M.D., B.H., Writing: İ.A., M.D., B.H.

Conflict of Interest: One of the authors, Burcu Hazer, is a member of the editorial board of the Cam and Sakura Medical Journal. The editorial and peer-review process was conducted independently of this author.

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