Research Article

Diagnostic value of ultrasonography in peroneal neuropathy

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Background/aim: Peroneal neuropathy at the fibular head (PNFH) is one of the most common entrapment neuropathies. Our aim in this study was to analyze the efficiency of ultrasonography in the diagnosis of PNFH.

Materials and methods: The study included 15 peroneal nerves of 12 patients with PNFH and 24 peroneal nerves of 12 healthy controls. PNFH confirmation was based on clinical and electrophysiological findings. All patients and controls underwent ultrasonographic evaluations for peroneal nerves. The cross-sectional area (CSA) was measured. Echogenicity of the nerve was evaluated by comparing it with the adjacent connective tissue deep under the subcutaneous fat.

Results: CSA measurement of the peroneal nerve is a valuable diagnostic tool in predicting PNFH (AUC: 0.87, 95% CI: 0.73–1.00, P < 0.01). The CSA cutoff value for diagnosing PNFH was found to be 0.115 cm^2 with 80% sensitivity and 99% specificity. Hypoechoic peroneal nerve in patients with PNFH was very frequent.

Conclusion: Ultrasonography is a useful technique in diagnosing PNFH. In addition to clinic and electrophysiological findings, it may improve diagnostic performance.

Key words: Ultrasound, peroneal nerve, peroneal neuropathy, fibular neuropathy

1. Introduction

Peroneal neuropathy is one of the most common mononeuropathies in the lower extremities and usually occurs at the fibular head where the nerve is superficial and vulnerable to injury. Peroneal neuropathy at the fibular head (PNFH) can result from a variety of conditions such as trauma, traction injuries, masses, entrapment, and external compression from prolonged immobilization. Patients with PNFH usually have weak toe and ankle dorsiflexion, weak foot eversion, and numbness over the lower lateral calf and the dorsum of the foot. Therefore, patients with sciatic neuropathy, lumbosacral plexopathy, or L5 radiculopathy may present a similar clinical pattern and differentiating PNFH from these conditions may sometimes be difficult (1,2).

The diagnosis of PNFH is based on clinical findings and electrophysiological studies. Electrophysiological evaluation is usually adequate for the diagnosis of PNFH. However, additional tests may be required, especially in nonlocalizing peroneal nerve lesions with severe axonal loss. Although ultrasonography has proven to be useful in entrapment neuropathies of the upper extremities

(3,4), there are few studies that investigated the validity of ultrasonography in the diagnosis of PNFH (5–8).

In this study, we analyzed ultrasonographic findings in patients with PNFH and evaluated the efficiency of ultrasonography in the diagnosis of PNFH.

2. Materials and methods

2.1. Patients and controls

This study included 15 peroneal nerves of 12 patients with PNFH and 24 peroneal nerves of 12 healthy controls. Three patients had PNFH bilaterally. The inclusion criteria were based on both clinical and electrophysiological findings. To make the clinical diagnosis, we looked for weak toe and ankle dorsiflexion, weak foot eversion, and sensory loss over the lateral calf and the dorsum of the foot. Local pain or Tinel's sign may also be present at the fibular head. Patients with any symptoms of polyneuropathy were excluded from the study. Patients with diseases related to polyneuropathy, hypothyroidism, diabetes mellitus, amyloidosis rheumatoid arthritis, or pregnancy were also excluded from the study. Histories of acute trauma, peroneal surgery, and duration of symptoms longer than

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12 weeks were other exclusion criteria. One patient who had peroneal nerve mass bilaterally was excluded from the study after the ultrasonographic evaluation. Healthy volunteers included subjects with no symptoms or signs of PNFH or systemic diseases that could be related to polyneuropathy.

The institutional ethics committee approved the study and all participants gave informed consent. The study was conducted according to the Declaration of Helsinki's Ethical Principles for Medical Research Involving Human Subjects.

2.2. Electrophysiological studies

Electrophysiological studies included needle electromyography (EMG) and nerve conduction studies (NCS) and were performed on a Medelec Synergy machine (Oxford Instruments Medical, Inc., Oxford, UK). Motor and sensory NCS were performed using the standard techniques of supramaximal percutaneous stimulation. Skin temperature of the extremities was between 31 and 32 °C.

Peroneal and tibial motor NCS, including F-waves, were performed bilaterally. Peroneal nerve compound muscle action potential (CMAP) was recorded from the extensor digitorum brevis (EDB) muscle by stimulating over the ankle, below the fibular head and popliteal fossa (the distance across the fibular head was 10–12 cm). If the recording of the EDB muscle could not localize the lesion, the peroneal motor study was repeated, recording from the tibialis anterior muscle by stimulating the area below the fibular head and popliteal fossa. The tibial nerve CMAP was recorded from the abductor hallucis muscle by stimulating the area posterior to the medial malleolus and at the popliteal fossa.

For sensory NCS we evaluated superficial peroneal and sural nerves bilaterally and antidromically. The stimulation was done at the lateral calf and recorded from the lateral ankle for the superficial peroneal nerve. For the sural nerve the stimulation was done at the posterior of the lateral calf and recorded from the posterior to the lateral malleolus. We compared the findings with the reference values used in our laboratory. Needle EMG studies of the tibialis anterior, extensor hallucis longus, peroneus longus, gastrocnemius, short head of biceps femoris, and gluteus medius muscles were also performed.

The electrodiagnostic criteria for PNFH were: 1) absolute slowing (<44 m/s) of the motor conduction velocity across the fibular head or 2) conduction block across the fibular head (any drop in amplitude or area of >20%). The reduced sensory nerve action potential amplitude of the superficial peroneal nerve, the reduced compound muscle action potential amplitude of the EDB muscle, or needle EMG abnormalities of peroneal nerve innervated muscles were additional criteria.

2.3. Ultrasonographic studies

All patients and controls underwent ultrasonographic evaluation of the peroneal nerve. An Aplio 500A (Toshiba Med. Systems Co., Ottowara, Japan) and a 7–14 MHz linear array transducer were used. Ultrasonographic images were taken when patients were in the lateral decubitus position with their knees semiflexed (20° to 30°). At least 5 cm of bilateral peroneal nerves just proximal to the level of fibular head was evaluated by ultrasonography. On transverse images, the common peroneal nerve was located between the fibular head laterally and the peroneus longus tendon medially. The course of the peroneal nerve was also evaluated in the sagittal plane (Figures 1 and 2). The cross-sectional area (CSA) of the nerve in transverse views was measured using continuous manual tracing, excluding the hyperechoic epineurial rim (Figure 3). The largest measurement obtained after multiple measurements was accepted as the actual CSA. Three or more CSA measurements for each nerve were done.
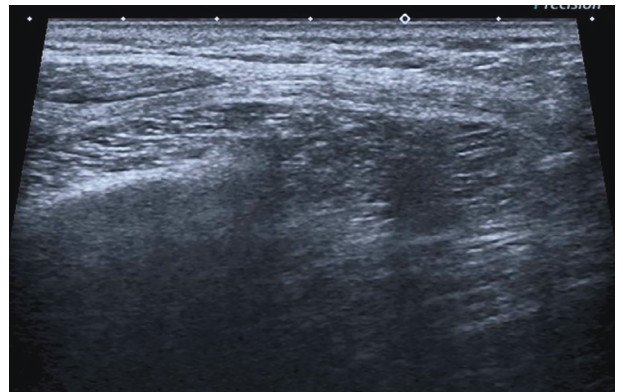
Figure 1. Normal peroneal nerve in sagittal ultrasonographic view (arrow heads) shows isoechoic nerve compared with adjacent connective tissue deep under the subcutaneous fat.
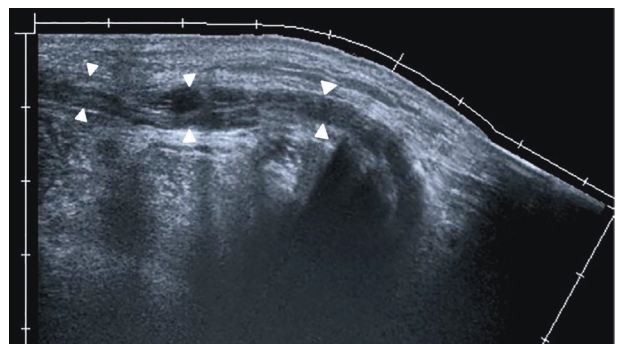
Figure 2. Extended-field-of-view longitudinal ultrasonographic image shows thick, hypoechoic peroneal nerve around the fibular head (arrow heads).
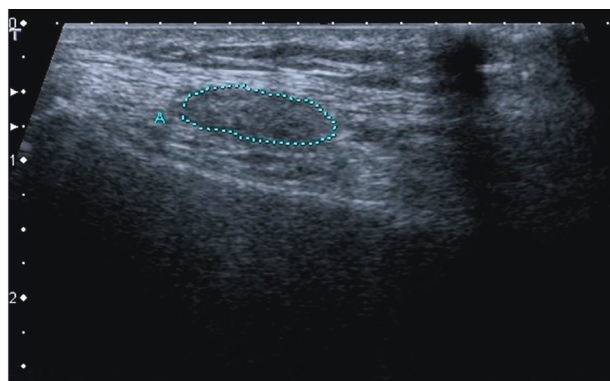
Figure 3. Cross-sectional area measurement of the nerve in transverse view using continuous manual tracing method, excluding the hyperechoic epineurial rim.

Echogenicity of the nerve was also evaluated. The adjacent connective tissue deep under the subcutaneous fat was used for comparison. The nerve was classified as hypoechoic if nerve reflectivity was low (Figure 2) and isoechoic when the nerve had the same reflectivity as the adjacent connective tissue (Figure 1). Nerves in control subjects had similar echo and architecture to tendons on ultrasonography (Figure 1).

A radiologist with more than 10 years of experience in nerve and soft tissue ultrasonography did the evaluations. The radiologist was blinded to the subject groups. The interval between ultrasonographic evaluation and the electrophysiological study was 1 week or less.

2.4. Statistical analysis

Statistical analyses were performed using SPSS 21.0 (IBM Corp., Armonk, NY, USA). Variables were investigated using Shapiro–Wilk tests to determine whether they were normally distributed. For the variables that were not normally distributed, a log 10 transformation was used to provide a normal distribution. Descriptive analyses are presented using mean ± standard deviation and number (%). Student's t and chi-square tests were used to evaluate variables and results with $P < 0.05$ were considered significant. A receiver operating characteristics (ROC) curve analysis was performed to assess the efficiency of the comparative techniques in PNFH diagnosis to determine sensitivity, specificity, and cutoff points.

3. Results

The mean age of the patients was 47.3 ± 14.9 years and the controls had a mean age of 47.3 ± 13.4 years. Duration of symptoms was 5.62 ± 4.35 weeks. Both groups had 9 men (75%) and 3 women (25%). No significant differences in age or sex were noted between patients and controls. The demographic, clinical, and ultrasonographic characteristics of patients and controls and electrophysiological findings

of the patients are summarized in Table 1. Three patients had PNFH bilaterally and nine patients had PNFH unilaterally. There were significant differences in CSA measurements between patients and controls (Table 2). CSAs of peroneal nerves and echogenicity showed no significant differences between the control group and the normal side of the patient group (Table 2). In the patient group, there were significantly more hypoechoic peroneal nerves than in the control group (Table 2).

ROC curve analysis determined that CSA measurement was a valuable diagnostic tool in predicting PNFH (AUC: 0.87, 95% CI: 0.73–1.00, $P < 0.01$). The CSA cutoff value for diagnosing PNFH was 0.115 cm^2 with 80% sensitivity and 99% specificity (Figure 4).

4. Discussion

Entrapment neuropathy of the peroneal nerve is caused mostly by its compression at the level of the fibular head (6). Reported risk factors are marked weight loss, forcible strength injury, trauma, surgery at nerve localization, and compression from prolonged immobilization (1,5). Other possible causes are compression by intrinsic and extrinsic nerve tumors, synovial cyst, ganglia, bone, and soft tissue tumors. Electrophysiological evaluation can usually localize the level of the nerve lesion but cannot give information about the underlying pathology. In our study, we incidentally found that one of our patients had a nerve sheet tumor bilaterally and that individual was excluded from the study. Ultrasonography is a useful and widely available technique for evaluating and differentiating these pathologies from idiopathic compression (9).

The efficiency of ultrasonography is proved in compressive neuropathies (3,4,9). There are very few studies that have investigated ultrasonographic findings in PNFH (5–8). Visser et al. (5) described a cutoff value of 0.08 cm^2 with a sensitivity of 90% after assessment of CSA in the most thickened part of the common fibular nerve. The study was designed to localize the level of pathology with ultrasonography. In nearly one-third of their patient group no localizations were done by electrophysiological testing. They also had a patient-control group with foot drop in whom diagnoses other than common fibular neuropathy were made. We believe these are the reasons for their relatively lower cutoff values.

Lo et al. (6) enrolled five patients with peroneal neuropathy and they measured the maximum transverse length, maximum transverse breadth, ratio of these two parameters, and CSA. They indicated that sonography was useful in diagnosing PNFH and hypothesized that the negative correlation between motor amplitude and transverse length and area suggested a relationship between nerve swelling and axon loss (6). In this study, controls had a mean CSA of 0.10 cm^2 (0.06–0.14 cm^2).

Table 1. Ultrasonographic findings and motor and sensory nerve conduction studies of the patients.

| Age/Sex | Side | Ultrasonography | | | | Nerve conduction studies | | | | | |
| | | CSA (cm²) | | Echo | | Right | | | Left | | |
		R	L	R	L	SA (µV)	MA (mV)	MCV (m/s)	SA (µV)	MA (mV)	MCV (m/s)
52/M	L	0.08	**0.33**	I	H	9.4	2.0/2.0/2.0	49.6/52.5	**NR**	**NR**	-
38/F	R, L	**0.14**	**0.14**	H	H	12	2.6/2.1/**1.9**	42.5/**35.1**	9	**1.1/1.1/0.9**	44.7/**37.3**
43/F	L	0.08	**0.23**	I	H	18.5	8.8/8.5/8.5	52.4/68.6	11.8	5.0/5.0/**1.2**	**29.1/24.4**
72/M	L	0.11	**0.75**	I	H	8	4.4/3.5/3.5	43.1/44.2	**NR**	**NR**	-
67/M	L	0.07	**0.25**	I	H	7.2	2.0/2.0/2.0	45/44	**NR**	**NR**	-
46/M	L	0.11	**0.12**	I	I	7.2	6.8/5.7/5.3	45.3/44	7.9	**NR**	-
61/M	R, L	**0.07**	**0.08**	I	H	10.6	2.1/2.1/2.0	44/**39**	**NR**	2.6/2.5/2.3	**41/38**
41/M	R	**0.26**	0.07	H	I	**NR**	3.8/2.2/**1.8**	**41.8/39**	12.2	5.9/4.9/4.8	44.8/44.7
47/M	L	0.07	**0.10**	I	I	**5.1**	2.0/2.0/2.0	44/44	11.1	**0.7/0.7/0.7**	44/**39**
32/M	R	**0.35**	0.14	H	H	13.1	3.3/2.5/2.3	46.6/**39**	18.7	2.2/2.0/2.0	43/44
18/M	R	**0.53**	-	H	-	19.8	7.2/6.6/**0.6**	49.6/**38.5**	20.3	5.7/5.5/5.5	50/47.4
50/F	R, L	**0.22**	**0.30**	H	H	9.2	**NR**	-	9.5	**NR**	-

F: Female, M: male, CSA: cross-sectional area, R: right, L: left, H: hypoechoic, I: isoechoic, Echo: echogenicity. SA: sensory amplitude, MA: motor amplitude, MCV: motor conduction velocity, NR: no response.
Ultrasonographic measurements in electrophysiologically pathologic nerves are in bold.
Pathologic electrophysiological values are in bold.

Table 2. Comparison of peroneal nerve CSA and echogenicity of the affected and the unaffected sides of patients with controls.

| | | Patients | Healthy controls | USP | Patients vs. controls | | USP vs. controls | |
					P-value		P-value	
CSA	Mean ± SD Range	0.258 ± 0.184 (0.07–0.75)	0.0913 ± 0.018 (0.06–0.12)	0.0913 ± 0.026 (0.07–0.14)	<0.001	t: 4.45	0.087	
US	H (n)	12 (80%)	2 (8.3%)	1 (12.5%)	<0.001	χ²: 20.6	0.726	χ²: 0.12
	I (n)	3 (20%)	22 (91.7%)	7 (87.5%)				

USP: Unaffected side of patients, CSA: cross-sectional area, US: ultrasonography, H: hypoechoic, I: isoechoic.

No cutoff was calculated, but patients with compressive neuropathy had CSAs of 0.21 cm² and above. In this study, the number of patients with common fibular neuropathy was low. They also had patients with extremely enlarged nerves (0.21–0.31 cm²), as we had in our patient group (0.07–0.75 cm²).

In the study of Meylaerts et al., the authors evaluated six patients with PNFH after weight loss (7). They measured CSA, including both long and short transverse diameters, and also evaluated differences in echogenicity.

They found a mean CSA of 0.18 ± 0.5 cm² in the control group. They indicated that CSA in the affected peroneal nerve did not differ much from that of the unaffected side; the most important sonography finding in the pathological peroneal nerve was the presence of spots with low signal reflectivity (7). We think that the reason for higher CSAs in controls and possibly in patients could be the technique used in calculating CSA. The ultrasonographic technique was not described in detail, but as far as we can ascertain from the figures, CSA measurements were done using an
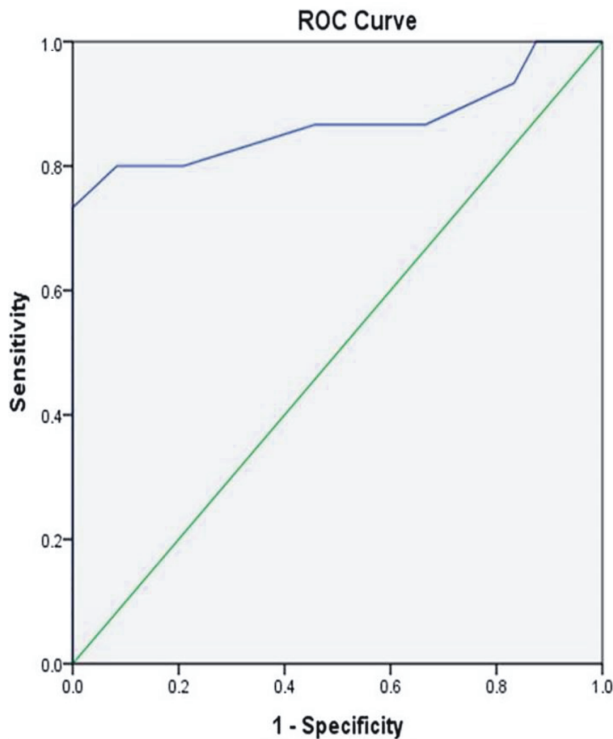
Figure 4. ROC curve analysis for CSA measurement for PNFH diagnosis.

automated ellipsoid ROI and the area measured did not exclude the echogenic rim around the nerve. This would explain the higher CSA measurements. In our study, we use manual tracing and excluded the echogenic rim around the nerve. We found a mean CSA of 0.0913 ± 0.018 cm^2 in the control group and 0.0913 ± 0.026 cm^2 in the unaffected side of the patient group. The difference was not statistically significant. The mean CSAs that we measured were closer to the other reported data (5,6,9). In these studies, there was lower echo in the affected sides. We used a similar evaluation method and found lower echogenicity in the affected peroneal nerve, which agrees with all other compressive neuropathies. In our study, there were two (8.3%) hypoechoic peroneal nerves in the control group and one (12.5%) in the unaffected side of the patient group.

Although a cutoff value of 0.115 cm^2 was calculated in our study, three peroneal nerves had CSA value below this limit (0.07, 0.08, and 0.10 cm^2). In two of these patients, nerve echogenicity did not solve the diagnosis problem because nerve echogenicity was normal; in one patient, the nerve was as hypoechoic as pathological nerves with high CSA.

Recently, Kim et al. described a cutoff value of 0.117 cm^2 with sensitivity of 85% and specificity of 90%, which is very close to our findings (8). The reason for relatively high specificity in our study could be the lower number of patients and extreme enlargement seen in a large percentage of them. Kim et al. noted that comparing the difference between the symptomatic side with the asymptomatic side or calculating the ratio would be helpful in diagnosis of PNFH (sensitivity 83% and 72%, specificity 97% and 97%) (8). When comparing the asymptomatic side with controls, we noted no significant difference in CSA measurements and found it unnecessary to compare differences between symptomatic sides and asymptomatic sides. However, we still believe it would be helpful in clinical settings. In our patient group, four patients had bilateral PNFH, and in one an ultrasonographic demonstration could not be done for the asymptomatic side. In eight patients there was PNFH unilaterally. In only one of eight patients with unilateral PNFH was the difference and the ratio of the symptomatic and asymptomatic side not concordant with the findings that Kim et al. described (8).

The relatively lower number of patients and subjective evaluation of echogenicity were limitations of our study. We noted isoechoic or normal nerve echogenicity in three (20%) affected nerves. Objective evaluation of nerve echogenicity could be a solution to this problem. We believe that the cause of hypoechoic nerves in controls could be PNFH with hidden clinical findings. Not doing electrophysiological evaluation of controls is another limitation of our study.

We think that CSA measurement of the peroneal nerve at the level of the fibular head and evaluation of nerve echogenicity by ultrasonography are useful techniques in diagnosing PNFH. In addition to clinical and electrophysiological findings, ultrasonography may improve diagnostic performance.

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