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Nerve Ultrasound Identifies Abnormalities in the Posterior Interosseous Nerve in Patients with Proximal Radial Neuropathies

Alexander R. Dietz, MD[a], **Robert C. Bucelli, MD, PhD**[a], **Alan Pestronk, MD**[a], and **Craig M. Zaidman, MD**[a]

[a]Washington University School of Medicine, Department of Neurology, St. Louis, MO 63110

Abstract

Introduction—The radial and posterior interosseous nerves (PIN) are prone to injury at multiple sites. Electrodiagnostic (EDX) studies may only identify the most proximal lesion. Nerve ultrasound could augment electrodiagnosis by visualizing additional pathology.

Methods—Retrospective examination of ultrasound and electrodiagnosis from 26 patients evaluated for posterior cord/radial/PIN lesions.

Results—Eighteen of 26 patients had abnormalities on electrodiagnosis (15 radial; 2 PIN; 1 posterior cord). Ultrasound identified 15 of 18 (83%) of the EDX abnormalities and provided additional diagnostic information. In 6 of 15 (40%) patients with EDX evidence of radial neuropathy, ultrasound identified both radial nerve enlargement and additional, unsuspected PIN enlargement (53% to 339% enlarged vs. unaffected side). Ultrasound also identified: nerve (dis)continuity at the trauma site (n=8); and nerve tumor (n=2; 1 with normal EDX).

Conclusion—In radial neuropathy, ultrasound often augments EDX studies and identifies a second lesion in the PIN. Further studies are required to determine the etiology and significance of this additional distal pathology.

Keywords

Ultrasound; radial nerve; posterior interosseous nerve; double crush syndrome; neuropathy

Introduction

Injuries to the radial nerve and its distal motor branch, the posterior interosseous nerve (PIN), are relatively common and can occur at multiple sites along the course in the arm[1,2]. Lesion localization is typically based on the pattern of clinical and electrodiagnostic findings. PIN neuropathy is distinguished from the more proximal radial neuropathy by sparing of sensation and sparing of strength in the triceps brachii and brachioradialis muscles. In patients with wrist and finger drop, lesion localization is clinically relevant and affects outcomes[3]. Definitive lesion localization may not always be possible with clinical

Address correspondence to: Craig Zaidman, MD; Washington University School of Medicine; Department of Neurology; 660 S. Euclid Ave, Box 8111; St. Louis, MO 63110; zaidmanc@neuro.wustl.edu; Phone: 314-362-6981; Fax: 314-362-3752.

and electrodiagnostic (EDX) examinations. As the radial and PIN encounter multiple potential entrapment sites along their course, it is possible that patients with radial neuropathy have a superimposed PIN lesion that is undetected, especially following trauma[4]. Dual lesions have been reported rarely, often following trauma but to our knowledge have not been systematically evaluated in the radial and PINs [5-8]. This may be because neither clinical nor EDX findings can clearly identify a superimposed PIN lesion in patients with a more proximal radial neuropathy.

Nerve ultrasound is a non-invasive and painless diagnostic modality that can readily identify abnormalities in both the radial and PIN [9-13] and can identify multiple pathologies in a single nerve distribution[14,15]. Nerve pathology identified using ultrasound includes nerve enlargement, change in nerve caliber, and alterations in nerve echogenicity and vascularity. Ultrasound is complementary to electrodiagnosis for evaluating poly- and mononeuropathy and provides additional information that influences clinical management[16-20]. Imaging nerves with ultrasound or magnetic resonance imaging (MRI) can provide data on the etiology of a neuropathy, such as laceration, tumor, or compression, and they can also reveal pathology disparate from the location suspected based on clinical exam and EDX studies. For instance, in patients with anterior interosseous nerve syndrome, MRI showed nerve pathology in select motor fascicles of the proximal median nerve rather than the anterior interosseous nerve [21]. In this study, we describe how ultrasound augments electrodiagnosis in the evaluation of patients with radial and/or PIN neuropathy and highlight examples of patients with abnormalities in both the radial and PIN.

Methods

This study was approved by our institutional review board. We identified and reviewed medical records of 53 patients referred for nerve ultrasound with concern for unilateral radial and/or posterior interosseous neuropathy from 1/2009 to 9/2014. We excluded 27 patients who did not undergo EDX studies and/or sonographic evaluation of both the radial and PIN (n=15), or who had prior surgery (i.e. nerve decompression/transfer) directly involving the radial or PIN (n=7), inflammatory polyneuropathies (n=3), or radiculoplexopathy (n=1), and 1 who had EDX evaluation 85 days prior to the ultrasound. Of the 26 patients included, EDX was performed on the same day as the ultrasound in 22 and within 35 days in 4. All patients were evaluated in our neuromuscular electrodiagnostic laboratory. In 1 patient, we also reviewed the nerve conduction studies performed at the University of North Carolina 2 months prior to the studies performed at our institution. We also reviewed the clinical examinations performed by the referring/consulting physicians, and noted the presence and pattern of weakness.

Nerve ultrasound was performed by CMZ using a Philips iu22 machine with an L12-5 or L15-7 probe. The radial nerve was visualized in the arm and forearm through its division into the posterior interosseous nerve. The posterior interosseous nerve was visualized from its division from the superficial radial sensory nerve to the crossing of the distal margin of the supinator muscle. Results of the ultrasound examination were characterized based on the reported final conclusion of the sonographer (CMZ) in the medical record. We identified abnormalities such as enlargement, tumor, displacement, impingement, or laceration in these

nerves qualitatively. We often also performed measurements of nerve cross sectional area, but due to the oblique course of the normal radial nerve and the very small and often separated fascicles of the normal appearing PIN we did not rely on quantitative values to define abnormalities. In the symptomatic arm, we measured the cross sectional area (CSA) of the radial nerve in all and the PIN in 13 of 26 patients. For comparison, in the contralateral, unaffected arm we measured the CSA of the radial nerve in11 of 26 (median 4.4 mm^2, range 3.4 mm^2 - 6.1 mm^2) and the PIN in 9 of 26 (median 1.8 mm^2, range 1.2 mm^2 - 2.3 mm^2) patients. Ultrasound abnormalities included nerve enlargement with caliber change at the lesion site, evidence of nerve trauma (laceration, displacement, or impingement from fracture, gunshot wound), or nerve tumor. Abnormalities were classified as involving the common radial nerve, posterior interosseous nerve, or both. For clarity, the deep motor branch of the radial nerve, identified from its division from the common radial nerve and proximal to the supinator muscle, was classified as the posterior interosseous nerve.

Electrodiagnostic testing was performed in our laboratory by neuromuscular specialists (all certified by the American Board of Electrodiagnostic Medicine) using standard techniques. All patients had radial motor and superficial radial nerve sensory nerve conduction studies recorded from the extensor indicis and anatomic snuffbox, respectively, as well as needle EMG of muscles innervated by the radial nerve and PIN. Conduction block was defined as >50% decrease in the proximal relative to the distal compound motor action potential (CMAP) amplitude. Electrodiagnostic abnormalities were localized based on neuroanatomic criteria[22] as follows: 1) Posterior interosseous neuropathy (includes lesions within and distal to the deep motor branch of the radial nerve), defined as active and/or chronic denervation of the muscles innervated by the PIN (i.e.: extensor indicis, extensor digitorum, or extensor carpi ulnaris) with sparing of muscles innervated by the more proximal branches of the radial nerve (i.e. brachioradialis, supinator, and triceps brachii), sparing of the radial sensory nerve action potential (SNAP), and/or conduction block localized to the forearm segment; 2) Radial neuropathy, defined as active and/or chronic denervation of muscles innervated by the radial nerve proximal to the deep motor branch/PIN (i.e. brachioradialis), an abnormal radial SNAP, or conduction block in the arm; 3) Posterior cord plexopathy, defined as denervation of the most proximal muscles innervated by the radial nerve (i.e. triceps brachii) and additional denervation of the deltoid and/or latissimus dorsi.

We classified a patient as normal if both ultrasound and electrodiagnosis were normal and as abnormal (neuropathy) if either was abnormal. Examiners were not blinded to clinical features or the results of the ultrasound or electrodiagnosis. We categorized the etiology of neuropathy based on the clinical history.

Results

The 26 patients (15 men) were age 17-79 years. Seven had both normal ultrasound and electrodiagnosis, and 19 had a neuropathy. Neuropathies (Table 1) were due to trauma (n=8), idiopathic (n=5), compression related to position during sleep or surgery (n=4), or tumor (n=2).

Eighteen had abnormal electrodiagnosis: 15, radial neuropathy; 2, posterior interosseous neuropathy; and 1 posterior cord brachial plexopathy (Table 1, electrodiagnostic details in Supplementary Table S1, available online). All (n=18) had fibrillation potentials or positive sharp waves and reduced recruitment in 1 or more muscles innervated by the radial and/or posterior interosseous nerves. Other electrodiagnostic abnormalities included: conduction block above the elbow (n=3) or in the forearm (n=1), a small or absent radial CMAP from the extensor indicis (n=15), and a small or absent radial SNAP (n=12).

Seventeen had abnormal ultrasound: 9 had radial neuropathy, 2 had posterior interosseous neuropathy, and 6 had both radial and posterior interosseous neuropathy (Table 1). Ultrasound abnormalities in the radial nerve were nerve enlargement with caliber change (n=10), transection (n=2), tumor (n=2), and displacement by surgical hardware with caliber change (n=1). Ultrasound abnormalities in the PIN were nerve enlargement with caliber change in all (n=8). Enlarged radial nerves had a median (range) CSA of 11.8 mm^2 (6.1 mm^2 – 35.1 mm^2). All enlarged radial nerves were either 44% - 176% larger than the unaffected side (n=7) or had CSA > 12 mm^2 (n=3). Enlarged PINs had a median (range) CSA of 5.1 mm^2 (2.9 mm^2 -7.9 mm^2) and, in 7, were 53-392% larger than the unaffected side. One very enlarged PIN (CSA 7.5 mm^2) was not compared to the unaffected arm. Ultrasound confirmed the electrodiagnostic abnormality in 15 of 18 (83%) patients (Table 2): 13 with radial neuropathy and 2 with posterior interosseous neuropathy.

Ultrasound often added additional information to the electrodiagnosis. In 6 of 15 (40%) patients with electrodiagnostic evidence of a radial neuropathy in the arm (patients #1-6, Table 1 and Figure 1), ultrasound identified enlargement of both the radial nerve in the arm (CSA 8.6 mm^2 -12.0 mm^2, all >44% larger than the contralateral side) and additional, distinct enlargement of the PIN within the body of the supinator muscle (CSA 2.9 -7.9mm^2, all >53% larger than the contralateral side, Figure 1). Ultrasound clarified or augmented electrodiagnosis in an additional 10 patients. Two had nerve tumors identified with ultrasound (1 with normal electrodiagnosis). Eight had traumatic neuropathies with no (n=7) or single (n=1) motor unit potentials in the finger extensor muscles; ultrasound identified nerve continuity in 6 and transection in 2.

The 6 patients (#1-6) with radial neuropathy and PIN enlargement had clinical findings consistent with radial neuropathy and similar electrodiagnosis to those without PIN enlargement (Table 1). None had nerve transection or direct trauma to the PIN. Of these 6 patients, 3 had trauma to the arm proximal to the elbow [2 humerus fractures (patients #2 and #3) and 1 gunshot wound (patient #4)], 2 had idiopathic onset (patients #1 and #6), and 1 had compression during sleep (patient #5). None of these patients had diabetes mellitus. Patients #1-5 had weakness in the brachioradialis. Patients #2-6 had abnormal sensation in the superficial radial nerve distribution. Following ultrasound and electrodiagnosis, 3 (patients #1, #3, and #6) had surgical release of the PIN and 1 (#1) of the radial nerve; all had nerve constriction identified intraoperatively.

Ten patients with electrodiagnosis of radial neuropathy had clinical follow up of brachioradialis and wrist/finger extensor strength 1 month – 6 years after the ultrasound examination. Five had PIN enlargement, and 5 did not. At last follow up, all 5 patients (#1,

#3, #4, #5, and #6) with radial neuropathy and PIN enlargement, but only 2 of 5 patients (#9 and #10) with radial neuropathy without PIN enlargement had weakness preferentially affecting muscles innervated by the PIN compared to the proximal radial nerve braches. One (#9) suffered a gunshot wound to the elbow just proximal to the takeoff of the PIN. Patients #2, 12, 13, 14, and 15 were lost to follow up or had insufficient examinations recorded.

Electrodiagnosis and ultrasound differed in 4 patients. One (patient #18) had electrodiagnosis of a posterior cord lesion and also had conduction block in the forearm/PIN following a displaced humerus fracture with internal fixation; ultrasound showed a normal PIN and an abnormal appearing radial nerve displaced by surgical screws in the distal arm. Two patients (#14 and #15) had electrodiagnosis of radial neuropathy at the spiral groove with conduction block (1 idiopathic, 1 Saturday night palsy) but had normal ultrasound. One patient (#19) had a radial nerve tumor identified on ultrasound but had normal electrodiagnosis.

Discussion

Nerve ultrasound identified dual, distinct pathologies in the radial and posterior interosseous nerves that were not suspected based on the primary mechanism of injury or electrodiagnostic results. This is similar to a previous case report of dual injuries in the radial and PIN following trauma[4]. In our patients with radial neuropathy, the etiology of the additional nerve enlargement in the PIN is unknown. Possible etiologies of PIN injury in patients with radial neuropathy could be: 1) mechanical (i.e.: strain or stretch) injury secondary to trauma to the proximal radial nerve; 2) the denervated PIN may be predisposed to a second, compressive injury, as hypothesized in “double crush syndrome” [23,24]; or 3) mechanical alterations in the denervated supinator muscle could lead to compression. Axon loss could also cause mild enlargement in the PIN, but it is unlikely to cause the marked enlargement noted in most of our patients[25].

Routinely imaging nerves as part of the diagnostic evaluation could improve identification of nerve pathologies not suspected based on the clinical exam or electrodiagnosis. The significance of these unsuspected alterations in nerve morphology is unknown. All patients in this study with ultrasound identified pathologies in both the PIN and radial nerve, and some patients without enlargement of the PIN, had weakness preferentially affecting the PIN innervated muscles at last follow up. Additional studies comparing clinical examination to electrodiagnostic and ultrasound results are required to determine how nerve imaging informs prognosis and impacts management.

Ultrasound often augmented electrodiagnosis in patients with radial or PIN lesions. Ultrasound confirmed the abnormal electrodiagnosis in most (83%) patients and added additional diagnostic information, such as visualizing unsuspected PIN enlargement, nerve continuity or laceration in trauma, or nerve tumors. In all, ultrasound augmented electrodiagnosis in 16 of 19 (84%) patients. The additional value of ultrasound to electrodiagnosis found in this study is similar to a previous study which found that ultrasound modified the diagnostic and therapeutic path in 42% of patients and played a confirmatory role in another 40%[16]. Similar to this prior study, our findings emphasize how

ultrasound is especially valuable in nerve trauma, as it can evaluate nerve continuity and describe the precise location of nerve injury [17,18,26,27].

This study has several limitations. We performed a retrospective evaluation, which limited our ability to systematically define the patients' signs and symptoms. Neither the ultrasonographer nor the electrophysiologists were blinded to clinical or diagnostic information, which could inflate the rate of concordance between ultrasound and electrodiagnosis. We also therefore could not determine the sensitivity or specificity of ultrasound or electrodiagnosis in radial or posterior interosseous neuropathy. Ultrasound in our study was performed by a single, experienced examiner, and results could differ at other institutions. Finally, all patients in our study had neuropathies with axon loss. Patients with less severe neuropathies may show different results.

In conclusion, ultrasound, as an addition to electrodiagnosis, improved the identification of superimposed PIN lesions in patients with proximal radial neuropathies. Forty percent of patients with radial neuropathy had abnormal PIN morphology identified with ultrasound. Further study is required to determine how the additional pathology identified with ultrasound in the PIN affects prognosis and management of the radial neuropathy.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Abbreviations

PIN	posterior interosseous nerve
MRI	magnetic resonance imaging
CSA	cross sectional area
CMAP	compound motor action potential
EDX	electrodiagnostic
SNAP	sensory nerve action potential

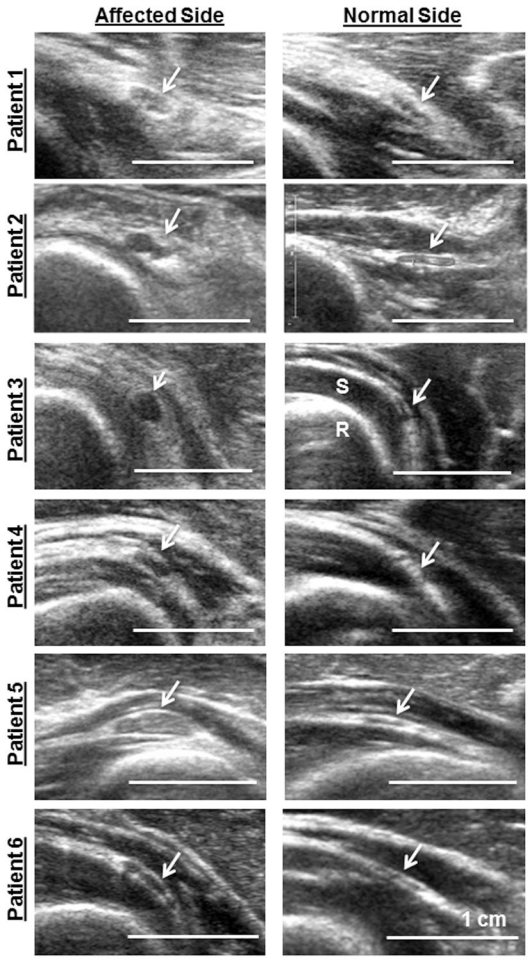

Figure 1.

Ultrasound images of the enlarged posterior interosseous nerve (arrows, left panels) compared to the normal, contralateral side (arrows, right panels) in 6 patients with electrodiagnostic evidence of a radial neuropathy. The radius (R) appears as bright and rounded deep to the supinator (S). White bar = 1 cm.

Table 1

Etiology and Findings of Electrodiagnosis and Nerve Ultrasound in Patients with Radial or Posterior Interosseous Neuropathy

Patient #	Etiology	EDX Result	NUS Result
1	Idiopathic	RN	RN + PIN
2	Humerus Fracture	RN	RN + PIN
3	Humerus Fracture	RN	RN + PIN
4	Gunshot Wound	RN	RN + PIN
5	Sleep Compression	RN	RN + PIN
6	Idiopathic	RN	RN + PIN
7	Humerus Fracture	RN	RN
8	Gunshot Wound	RN	RN
9	Gunshot Wound	RN	RN
10	Post- Surgery	RN	RN
11	Tumor	RN	RN
12	Idiopathic	RN	RN
13	Idiopathic	RN	RN
14	Idiopathic	RN	Normal
15	Sleep Compression	RN	Normal
16	Elbow Fracture	PIN	PIN
17	Idiopathic	PIN	PIN
18	Humerus Fracture	Posterior cord	RN
19	Tumor	Normal	RN

Legend: EDx: electrodiagnosis; NUS: nerve ultrasound; RN: radial neuropathy; PIN: posterior interosseous neuropathy. Patients #1-6, in bold, had both radial and posterior interosseous neuropathy identified with nerve ultrasound.

Table 2

Location of Neuropathy Based on Nerve Ultrasound vs. Electrodiagnosis

	Electrodiagnosis					Total (based on NUS)
Nerve Ultrasound	**Lesion Location**	**Posterior Cord**	**Radial**	**PIN**	**None**	
	Radial only	1	7	0	1	9
	Radial + PIN	0	6	0	0	6
	PIN only	0	0	2	0	2
	None	0	2	0	7	9
Total (based on EDX)		1	15	2	8	N=26

NUS: nerve ultrasound, EDX: electrodiagnosis, PIN: posterior interosseous nerve