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OPEN Case Report

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ABSTRACT

Penetrating lacerations to the hand are a common cause of nerve injury and can lead to debilitating pain and numbness in the distribution of the nerve affected. Owing to an overlap in the cutaneous innervation from different sensory nerves, clinically identifying the injured nerve can be difficult. We present a novel case of isolated injury to the palmar cutaneous nerve from a penetrating knife injury which was detected using 'comparison waveform' nerve conduction studies. Using this technique, we can isolate injuries to the palmar cutaneous branch of the median nerve (PCB_{mdn}) from the median nerve, dorsal radial sensory nerve, and lateral antebrachial cutaneous nerve. In addition, sensory nerve testing identified conduction block as the mechanism of injury, which resolved after surgery at 8 weeks postoperatively. Preoperative nerve conduction study can discern the level of nerve injury to PCB_{mdn} only, thus eliminating the need for median and radial nerve exploration at the forearm, unnecessary incisions, pain, and scarring. The objective of this case report is to illustrate the value of preoperative comparison waveform nerve conduction study, particularly the PCB_{mdn}, in patients presenting with neurologic deficits who have sustained penetrating lacerations to the hand.

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The palmar cutaneous branch of the median nerve (PCB_{mdn}) is the last branch to arise from the radial aspect of the main trunk of the median nerve approximately 4 cm proximal to the distal wrist crease, and it provides cutaneous sensation to the thenar eminence and mediolateral region of the palmar skin.[1] Apart from the PCB_{mdn} nerve, the skin over the thenar eminence may receive additional cutaneous innervation from the dorsal radial sensory nerve and lateral antebrachial cutaneous nerve.[2-4] In addition, cadaveric studies demonstrate a plexiform communication(s) between each of these nerves ranging from 4 to 40% of specimens dissected.[2-4] This variety and variability of cutaneous innervation at the thenar eminence creates a diagnostic dilemma in the setting of injuries to this region of the hand.

Adjunct objective studies would assist preoperative planning for these patients.

Cases of focal neuropathy of the PCB_{mdn} related to a ganglion cyst,[5,6] iatrogenic causes,[7,8] an atypical palmaris longus muscle, entrapment from fascial structures,[7,9] and penetrating injuries[10] are recorded. However, the diagnosis is challenging because the abnormality of the PCB_{mdn} is often inconsistent and is inherently difficult to assess. Here, we present a case of isolated injury to the palmar cutaneous nerve from a penetrating traumatic injury which was detected using 'comparison waveform' nerve conduction studies. Previous methods of PCB_{mdn} measurement are antidromic or orthodromic in nature, with sensitivities of 63 to 75%.[11-14] Given these reports, however, the electrophysiological measurement of the PCB_{mdn} remains challenging because of its anatomy; the diameter of the nerve is small, and it is in close proximity to dorsal radial sensory nerve and lateral antebrachial cutaneous nerve branches. We have discovered that PCB_{mdn} can be reliably determined by antidromic testing as described and in particular comparison of the waveform to the contralateral PCB_{mdn} as well as the dorsal radial sensory and lateral antebrachial nerve waveforms. This technique is able to isolate PCB_{mdn} sensory conduction and identify potential contributions from the radial sensory and lateral antebrachial sensory nerves. Use of this technique may be a valuable adjunct to routine nerve conduction studies in preoperative planning for traumatic hand lacerations.

Case Report

The patient is a 42-year-old right hand-dominant woman who sustained a penetrating injury along the radial aspect of the left distal forearm/radial wrist caused by an accidental knife injury 2 days before presentation. The trajectory and depth of the injury extended toward the midline of the distal volar forearm. The patient presented to the emergency department that day where the wound was irrigated and sutured. On presentation in our office, the patient reported persistent pain across the radial aspect of the left wrist/distal forearm with radicular symptoms up the arm, numbness in the thenar eminence, and volar-radial wrist, and occasional pins and needles in the fingers. Functionally, she had difficulty opening her medication bottles and driving, secondary to pain.

Physical examination was notable for a 2 cm longitudinal laceration at the left radial wrist (Figure 1) along with diffuse paresthesias in the left median nerve distribution. Thumb to small finger opposition was 2 cm on the left and 0 cm on the right. Distance to palmar crease was within 0 for all fingers bilaterally. Given the patient's clinical examination, there was suspicion for median nerve and/or median or radial nerve branch injury and surgery was recommended. However, given the diffuse nature of the paresthesias and unclear involvement of median nerve, PCB_{mdn}, or dorsal radial sensory nerve, preoperative neurodiagnostic testing was

Figure 1

Preoperative clinical photograph.

obtained to determine the location and extent of nerve injury more precisely.

Electrodiagnostic Testing

The patient underwent routine bilateral nerve conduction studies (NCS) and monopolar needle electromyographic testing using the Cadwell Sierra Summit machine. Hand temperature was maintained at or above 32°C using a warming lamp (TDP CQ Series) throughout the testing procedure.

Nerve conduction studies for median distal sensory latency values in patients with carpal tunnel syndrome vary by study with a weighted sensitivity of 73.4% and weighted specificity of 93.6%.[15] With clinically suspected sensory loss to the skin of the thenar eminence, examiners may incorporate either orthodromic or antidromically applied stimulation when assessing the palmar cutaneous branch of the median nerve (PCB_{mdn}). Our laboratory has extensive testing experience with the antidromic approach using methods previously described.[12,13] Using orthodromic applied stimulation, 75% sensitivity and 100% specificity values have been reported for the palmar cutaneous nerve (PCB_{mdn}).[14] Using NCS testing for assessing anomalous innervation has demonstrated the utility and value in the surgical hand setting.[16]

In our patient, further testing including antidromic sensory nerve testing was conducted using a technique previously described by stimulating the PCB_{mdn} nerve 10-centimeters lateral to the flexor carpi radialis tendon (S1) while recording the cutaneous response across the thenar aspect of the skin (G1)[17] (Figure 2). We also assessed for the potential innervation to the thenar skin by stimulating the radial sensory nerve 10 centimeters along the radial forearm (S2) and lateral antebrachial cutaneous nerve just along the lateral border of the distal biceps tendon at the elbow (S3).[17] We performed a 'comparative analysis' of the sensory nerves supplying the skin of the affected thenar eminence to provide a greater understanding to the patient's clinical complaints, by comparing PCB_{mdn} waveform amplitude to the contralateral unaffected side, and to bilateral radial sensory nerves and lateral antebrachial cutaneous nerves. During testing, the gain was set at 10 microvolts for better visualization of the desired waveform using a low-intensity graded stimulus. The expected normative value for the PCB_{mdn} nerve peak latency is less than 2.7 ms using 10-centimeters with a conduction velocity at or > 38 m/s (Figure 3).

In our patient, preoperative NCS demonstrated an absent left PCB_{mdn} nerve response and normal right PCB_{mdn} nerve response (peak latency 2.1 ms; onset to peak amplitude 3.4 mV, conduction velocity 48 m/s).

Figure 2

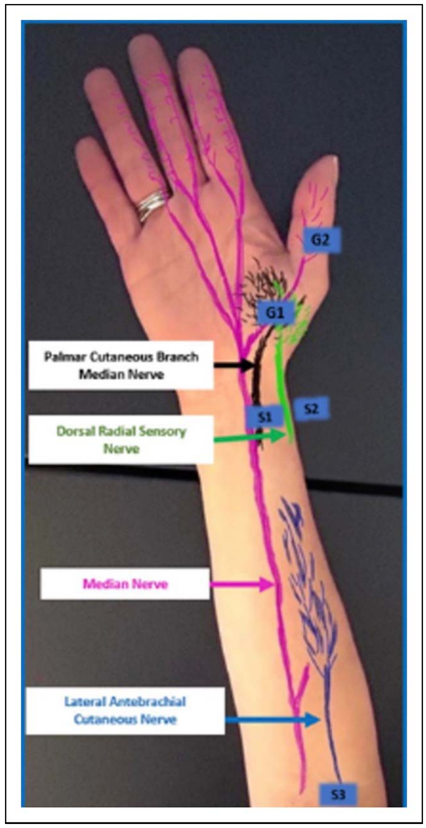


Diagram of the nerve conduction study setup. S1- Stimulus site 1: Palmar cutaneous branch of median nerve 10 cm from G1. S2- Stimulus site 2: Dorsal radial sensory nerve 10 cm from G1. S3- Stimulus site 3: Lateral antebrachial nerve tape measure antecubital fossa to G1. G1: recording electrode across the thenar eminence. G2: Reference electrode.

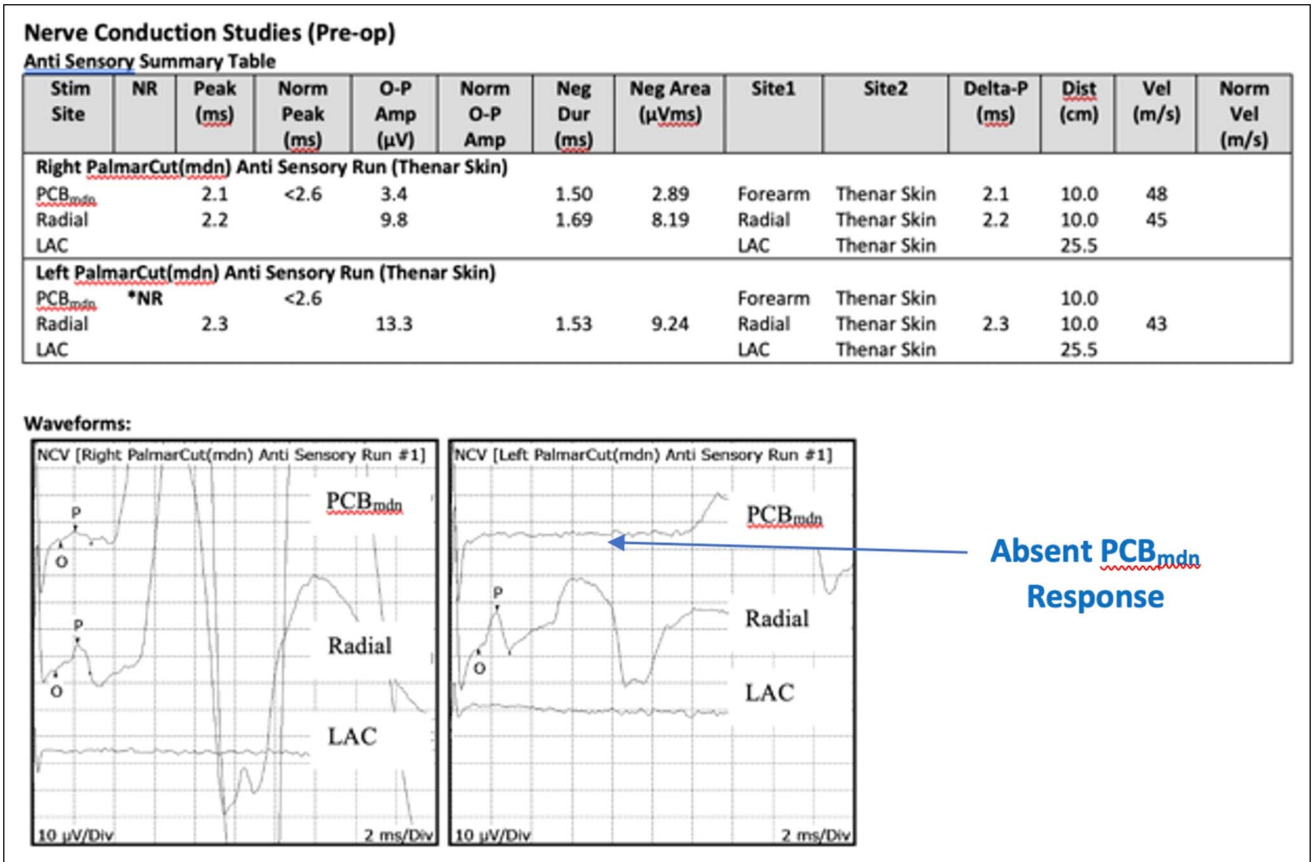
Preoperative testing also confirmed normal bilateral radial sensory nerve contributions to the skin of the thenar eminence and no lateral antebrachial cutaneous nerve contribution (Figure 3).

Surgical Findings

The left upper extremity was sterilely prepped and draped. The laceration (Figure 4A) was extended proximally to encompass the total length of 4 cm. Exploration was notable for partial FCR tendon laceration (Figure 4B). The PCB_{mdn} was localized because it branched from the median nerve proximal to the zone of injury (Figure 4B, scissor tip). However, on examination of the deep FCR tendon sheath, a small rent was noted (Figure 4, C and D forceps tip closeup), which was in close proximity to the PCB_{mdn} passing underneath (Figure 4E).

The sheath fascia was released, revealing the PCB_{mdn} in its entirety (Figure 4F). The aspect of the PCB_{mdn} proximal to the sheath appeared engorged. There were small rents in the epineurium and to a communicating

Figure 3



Nerve Conduction Studies (Pre-op)

Anti Sensory Summary Table

Stim Site	NR	Peak (ms)	Norm Peak (ms)	O-P Amp (µV)	Norm O-P Amp	Neg Dur (ms)	Neg Area (µVms)	Site1	Site2	Delta-P (ms)	Dist (cm)	Vel (m/s)	Norm Vel (m/s)
Right PalmarCut(mdn) Anti Sensory Run (Thenar Skin)													
PCB_{mdn}		2.1	<2.6	3.4		1.50	2.89	Forearm	Thenar Skin	2.1	10.0	48	
Radial		2.2		9.8		1.69	8.19	Radial	Thenar Skin	2.2	10.0	45	
LAC								LAC	Thenar Skin		25.5		
Left PalmarCut(mdn) Anti Sensory Run (Thenar Skin)													
PCB_{mdn}	*NR		<2.6					Forearm	Thenar Skin		10.0		
Radial		2.3		13.3		1.53	9.24	Radial	Thenar Skin	2.3	10.0	43	
LAC								LAC	Thenar Skin		25.5		

Chart showing the preoperative nerve conduction study findings. PCB_{mdn} = palmar cutaneous branch of median nerve, radial = dorsal radial sensory nerve, NR = no response, ms = milliseconds, µV = microvolts, O-P = onset to peak, cm = centimeters, m/s = meter/second.

artery, but no laceration of nerve fascicles was noted. The rents and the artery were repaired (Figure 4G).

Postoperative Course

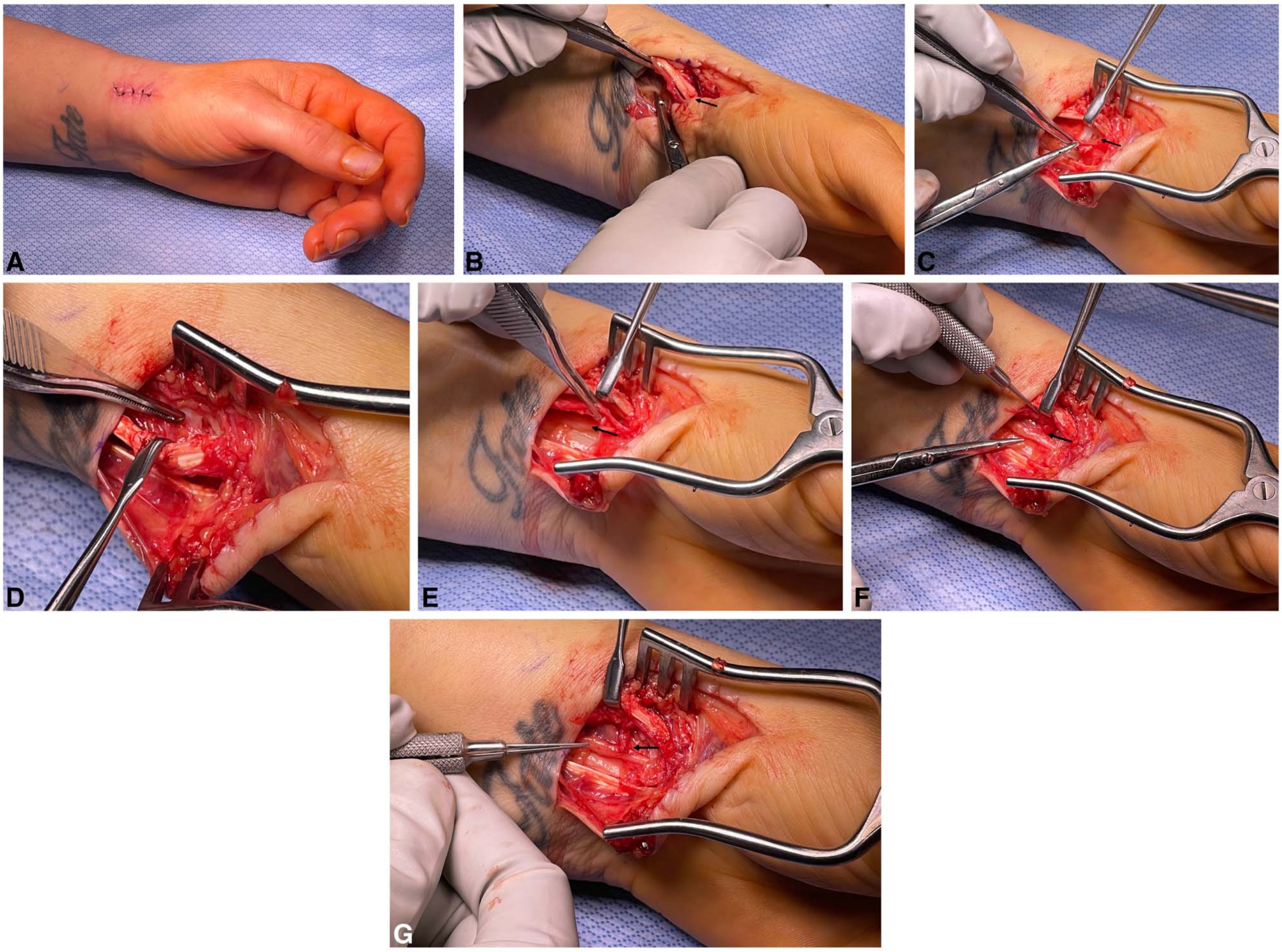
The patient was re-evaluated on postoperative day 9. The wound was well-healed, and sutures were removed. The patient subjectively had no paresthesias and on examination, sensation was intact to light touch in all nerve distributions of bilateral upper extremities. At 8 weeks post-op, the incision site was healed (Figure 5). The patient continued to report no paresthesias, and her clinical examination revealed normal peripheral sensory and motor function. A follow-up phone call was conducted six months postoperatively, and the patient remains asymptomatic.

Postoperative NCS demonstrated a normalized left PCB_{mdn} nerve response 8 weeks after surgery (peak latency 2.5 milliseconds; onset to peak amplitude 6.6 microvolts, conduction velocity 40 meters/second) (Figure 6). The restoration of a previously absent left PCB_{mdn} nerve response is most consistent with the resolution of a complete sensory conduction block abnormality after the surgical intervention.

Discussion

Penetrating lacerations to the hand are a common and debilitating cause of nerve injury. Clinical presentation includes the laceration, pain, and numbness in the distribution of the nerve affected. Although the decision to pursue surgery in these cases is straightforward, discernment of nerve involvement may not be. Here, we present a novel case of isolated injury to the palmar cutaneous nerve from a penetrating knife injury which was detected using electrodiagnostic techniques. Guided by the clinical presentation, we feel comparison waveform NCS is a valuable adjunct to routine nerve conduction studies for preoperative planning in the setting of traumatic hand injuries (Figure 7).

Figure 4



Intraoperative clinical photographs. **A,** Sutured laceration. **B,** Initial wound exploration, identifying FCR partial laceration (black arrow) and localization of PCB_{mdn} (scissor tip). **C,** A rent identified in the deep FCR sheath (black arrow), shown in close-up (tip of the forceps) (**D**). **E,** PCBmdn identified underneath the rent in FCR sheath (black arrow). **F,** PCB_{mdn} exposed in its entirety, with lacerated communicating artery and epineurium (black arrow). PCB_{mdn} proximal to the lacerated artery appears bulbous and congested (scissor tip). **G,** PCB_{mdn} (scissor tip) after repairing the rents in epineurium and communicating artery (black arrow).

Figure 5

Clinical photograph at 8 weeks postoperatively.

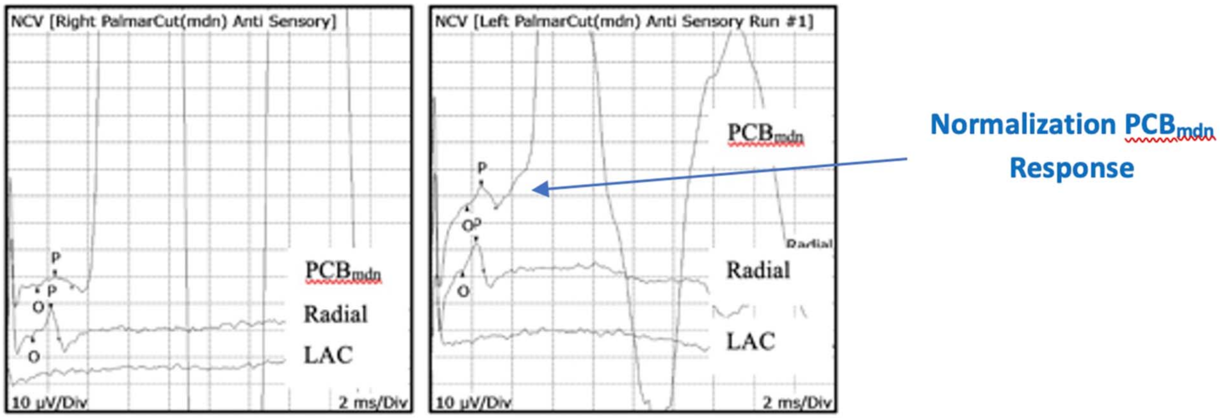
Figure 6

Nerve Conduction Studies (Post-op)

Anti Sensory Summary Table

Stim Site	NR	Peak (ms)	Norm Peak (ms)	O-P Amp (µV)	Norm O-P Amp	Neg Dur (ms)	Neg Area (µVms)	Site1	Site2	Delta-P (ms)	Dist (cm)	Vel (m/s)	Norm Vel (m/s)
Right PalmarCut(mdn) Anti Sensory (Thenar Skin)													
PCB_{mdn}		2.3	<2.6	3.3		1.72	3.47	Forearm	Thenar Skin	2.3	10.0	43	
Radial		2.2		9.5		1.28	5.40	Radial	Thenar Skin	2.2	10.0	45	
LAC								LAC	Thenar Skin		25.5		
Left PalmarCut(mdn) Anti Sensory (Thenar Skin)													
PCB_{mdn}		2.5	<2.6	6.6		1.44	4.64	Forearm	Thenar Skin	2.5	10.0	40	
Radial		2.2		10.1		1.03	6.06	Radial	Thenar Skin	2.2	10.0	45	
LAC								LAC	Thenar Skin		25.5		

Waveforms:



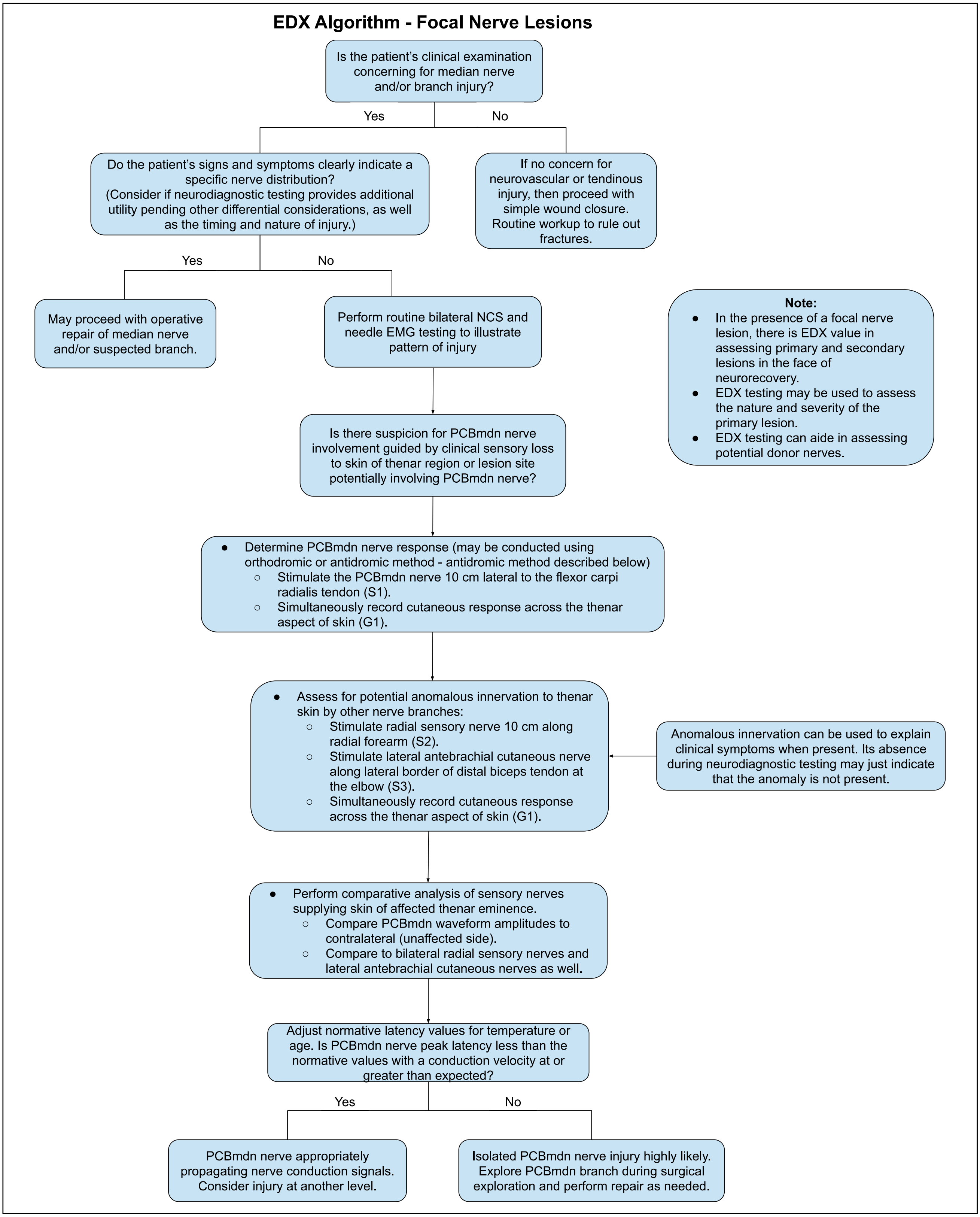
Postoperative nerve conduction study findings (8 weeks). PCB_{mdn} = palmar cutaneous branch of median nerve; radial = dorsal radial sensory nerve; NR = no response; ms = milliseconds; µV = microVolts; O-P = onset to peak; cm = centimeters; m/s = meter/second.

Focal neuropathy of the PCB_{mdn} is rare, with a few cases citing causes related to a ganglion cyst,[5,6] complications after surgical exploration,[7,8] atypical palmaris longus muscle, and entrapment from fascial structures.[7,9] Additional studies reported on the frequency of PCB_{mdn} neuropathy in carpal tunnel syndrome[18] and reported high sensitivity (75%) and excellent specificity(100%) values when conducting the PCB_{mdn} nerve study. This case report provides both clinical and electrophysiologic evidence in support of a complete conduction block lesion involving the PCB_{mdn} nerve which resolved after surgical repair of the blood supply to this nerve and release of the compressive fascia.[19,20]

This case report demonstrated cutaneous innervation to the thenar eminence from both the PCB_{mdn} and dorsal radial sensory nerves with no additional contribution from the lateral antebrachial cutaneous nerve. No study has previously been able to reliably isolate PCB_{mdn} sensory conduction via a 'comparison waveform' technique, where the PCB_{mdn} is compared with the contralateral unaffected side and with the radial sensory and lateral antebrachial sensory nerves. This technique was of particular value in this case since given the diffuse nature of paresthesias in our patient preoperatively, initial preoperative planning included median nerve exploration at the forearm and carpal tunnel release. Our preoperative NCS discerned the level of nerve injury to PCB_{mdn} only, thus eliminating the need for median nerve exploration at the forearm, unnecessary incisions, pain, and scarring. In our patient, the absence of the PCB_{mdn} nerve response guided by the clinical presentation during the preoperative evaluation suggested either a potential conduction block (eg, complete neurapraxia) issue or severe axonopathic process. The early restoration of the PCB_{mdn} nerve response supports the primary pathophysiologic abnormality as a conduction block process, a finding which has heretofore been well-accepted in motor nerve electrodiagnostic testing, but with caution when conducting sensory testing.[21]

When there is clinical evidence of sensory abnormality involving the thenar eminence in the presence of a traumatic injury, surgical management has not routinely involved preoperative electrodiagnostic testing because of timing,

Figure 7



Electrodiagnostic algorithm for focal nerve lesions. Algorithm of the electrodiagnostic approach used in this case report to evaluate PCB_{mdn} injury in the setting of evaluation and surgical management of penetrating lacerations to the hand. EDX = electrodiagnostic.

availability, and ability to detect individual sensory nerve branch contributions to this area. For instance, in our patient, preoperative electrodiagnostic testing for median nerve involvement at the wrist (eg, for carpal tunnel syndrome) would miss a potential concurrent lesion involving the PCB_{mdn}. Here, additional consideration as to the pattern of clinical findings and mechanism of injury led us to investigate further, with preoperative NCS to include examination of the PCBmdn, dorsal radial sensory nerve, and lateral antebrachial cutaneous nerve, compared with the contralateral side. In this manner, we were able to precisely identify the level of nerve injury. This finding was validated by surgical exploration, repair, and postoperative NCS. This case report is a clear example of the ability to accurately measure the PCBmdn in the setting of traumatic injuries to the upper extremity. We feel the utility of this ability is important not only to preoperative planning for traumatic lacerations but also useful in patients with neurapraxic injuries including carpal tunnel syndrome. For example, previous literature has noted the need to explore PCBmdn in routine carpal tunnel release for neurapraxic injuries because other investigators have noticed PCBmdn abnormalities in 63% of patients with carpal tunnel syndrome[15]. We are currently adopting our technique in a larger study of patients with carpal tunnel syndrome (manuscript in preparation). In our case report presented here, contralateral testing and the consistency in the obtained waveform responses over time supports the restoration of a previously absent PCB_{mdn} nerve response.

In summary, reliable NCS of the PCBmdn has not previously been documented. We feel this case study demonstrates that the PCBmdn can be reliably evaluated using NCS and suggests conduction block as a mechanism of injury that can be detected using sensory nerve testing. Inclusion of the PCBmdn nerve into the testing referral was beneficial in this case and should be incorporated within the routine testing when clinically indicated.

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