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Utilization of Nerve Conduction Studies for the Diagnosis of Polyneuropathy in Patients with Diabetes: A Retrospective Analysis of a Large Patient Series

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Abstract

Background:
Diabetic polyneuropathy (DPN) is a disabling complication of diabetes mellitus. A population-based analysis of physician utilization of nerve conduction studies (NCS) for the assessment of DPN was conducted.

Methods:
All electrodiagnostic encounters over a 30-month period using a computer-based neurodiagnostic instrument linked to a data registry were analyzed retrospectively. The DPN case definition was abnormal sural and peroneal nerve conduction.

Results:
The study cohort consisted of a total of 63,779 electrodiagnostic encounters performed by 3468 physician practices. Primary care and internal medicine physicians represented 80.1% of the practices and accounted for 65.7% of the encounters. Endocrinologists represented 4.6% of the practices and 20.1% of the encounters. The demographics of patients were 52.7% female; 63.4 ± 11.8 (mean ± standard deviation) years (age); 168.1 ± 10.9 cm (height); 92.2 ± 22.6 kg (weight); and 32.6 ± 7.2 kg/m^2 (body mass index). The most common peroneal abnormality was F-wave latency (33.6%). The sural nerve response latency and amplitude parameters had similar abnormality rates (58.3 and 62.7%). DPN was identified in 52.6% of the encounters; in another 19.3% no neuropathy was found.

continued →

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Abbreviations: (BMI) body mass index, (CMAP) compound muscle action potential, (DML) distal motor latency, (DPN) diabetic polyneuropathy, (DSL) distal sensory latency, (F-wave) F-wave latency, (NCS) nerve conduction studies, (PM&R) physical medicine and rehabilitation, (SNAP) sensory nerve action potential

Keywords: diabetic polyneuropathy, nerve conduction study, peroneal nerve, sural nerve

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Abstract cont.

Conclusions:
For over 70% of the patients, the specific diagnostic question of the presence of DPN was addressed by NCS with evidence-based criteria. The demographic features were strongly associated with risk of diabetes and DPN, suggesting that NCS were applied to appropriate demographic subgroups. The rate of DPN was also comparable to levels seen by academic electromyography laboratories. In 32.6% of the encounters the NCS suggested a posttest diagnosis other than DPN. This rate was similar to the results of referral to traditional electromyography laboratories. This study demonstrated that NCS using computer-based electrodiagnostic equipment was a suitable tool for the diagnosis of DPN. Furthermore, this technology permits examination of DPN in large populations.

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Introduction

Diabetic neuropathies are a disabling complication of diabetes mellitus. The most common form is a chronic distal symmetric sensorimotor polyneuropathy [diabetic polyneuropathy (DPN)], which has a prevalence of about 50%[1] and an estimated annual direct cost of $11 billion in the United States.[2] The clinical and economic burden of DPN stems from its central role in the pathophysiology of foot ulceration and lower limb amputation,[3] reduction in quality of life and decreased activities of daily living,[4] and susceptibility to falls and fractures.[5] Intensive glycemic control slows the progression of DPN but does not prevent or arrest its development.[6] The development of targeted pharmacological agents is an active area of research and human clinical trials.[7]

Diabetic polyneuropathy is underdiagnosed by both endocrinologists and nonendocrinologists.[8] The routine evaluation of DPN is based on patient symptoms and a physical examination, which may include the Semmes-Weinstein monofilament and the 128-hertz tuning fork. However, simple screening methods are of limited value in early neuropathy,[9] in the presence of neurological comorbidities,[10] and for the elderly.[11] Nerve conduction studies (NCS) are the most sensitive and specific DPN detection method.[9] Their use is recommended for quantitative confirmation DPN in clinical practice.[12] Expanded access to NCS has the potential for early diagnosis and improved outcomes.[10] To fully realize this potential, increasingly sophisticated technology has been incorporated into devices that perform NCS.[13] With the aid of these advances, a wide array of physicians, including those in primary care, internal medicine, and endocrinology, have integrated NCS into their clinical practice.[14,15]

Studies have shown that computer-based electrodiagnostic instruments are accurate and reliable[13] and have suggested that they may have an important role in the detection of DPN in primary diabetes care settings.[16,17] The primary aim of this study was to assess the utility of this technique in a large patient series. This study involved a population-based analysis of physician utilization of nerve conduction studies for the assessment of DPN. Utilization measures included demographic characteristics of the tested population, rate of nerve conduction abnormalities, and relevance of diagnostic outcomes.

Subjects and Methods

An electrodiagnostic encounter was defined as all nerve conduction tests performed on the same patient over a 24-hour period. All electrodiagnostic encounters between January 1, 2005 and June 30, 2007 using a neurodiagnostic instrument (NC-stat®; Neurometrix, Inc., Waltham, MA) linked to a data registry[13] were analyzed retrospectively. Each encounter was tagged with the self-identified physician specialty. Physicians using the instruments during this period were unaware of the eventual research use of data and were therefore blinded to the study. In addition to raw nerve conduction data, the data registry stored the patient age, gender, height, weight, and the primary study purpose as entered by the performing

physician. Inclusion criteria were electrodiagnostic encounters intended to assess diabetic neuropathy for which nerve conduction data were available for at least one peroneal and sural nerve.[18] Exclusion criteria were encounters with incomplete demographic information. The study was conducted with Institutional Review Board approval (#99000266, Copernicus Group, Gary, NC).

Nerve conduction parameters were derived from computer-based cursor assignments of supramaximally stimulated response waveforms and were normalized to standardized temperatures using linear correction factors. The parameters evaluated included the distal motor latency (DML), compound muscle action potential (CMAP) amplitude measured from baseline to the negative peak, mean F-wave latency (F-wave), distal sensory latency (DSL) measured to the negative peak, and sensory nerve action potential (SNAP) amplitude measured from the negative to positive peak. Measurements were flagged as abnormal if they were outside normal limits after adjusting for patient's age and height. Normal limits were set at the 97.5th percentile for latency parameters and at the 2.5th percentile for amplitude relative to disease-free controls. Percentiles between 90 and 97.5 for latency and between 2.5 and 10 for amplitude were flagged as borderline. All nerve conduction parameters could not be obtained in every encounter because of technical errors or patient-specific factors, including severe artifact and A-waves obscuring the onset of F-waves. The mean F-wave latency was calculated when at least three F-wave responses were measured. The mean F-wave latency was flagged as absent if sufficient F-wave responses were not available. The abnormality rate for a parameter was defined as the percentage of nerves outside normal limits. Absent responses were considered abnormal for DML, CMAP, DSL, and SNAP. Only a prolongation of the mean F-wave latency was considered abnormal; absence of recordable F-waves was considered inconclusive for the purpose of assessing polyneuropathy. The DPN case definition was an abnormal sural (DSL and/or SNAP) and abnormal peroneal (CMAP and/or F-wave) response.[18] When bilateral sural nerves were tested, both sural nerves had to be abnormal to meet the DPN case definition.

Results

A total of 63,779 electrodiagnostic encounters performed by 3468 different physician practices satisfied the inclusion and exclusion criteria. Among them, 2007 (3.1%) were repeat studies of the same patient. A total of 52.7% of patients were female; the mean patient age was 63.4 (±11.8) years; mean height was 168.1 (±10.9) cm; mean weight was 92.2 (±22.6) kg; and mean body mass index (BMI) was 32.6 (±7.2) kg/m^2. Demographic characteristics stratified by age are listed in **Table 1**. The most notable age-related factor was BMI, with less obesity in young and elderly patients. The distribution of encounters by physician specialty is provided in **Table 2**. In combination, primary care and internal medicine physicians represented 80.1% of the practices and accounted for 65.7% of the encounters. Endocrinologists represented 4.6% of practices but were responsible for 20.1% of the encounters.

A total of 123,590 peroneal and 67,942 sural nerves were evaluated. Peroneal and sural nerves were tested bilaterally in 93.6 and 6.5% of the patients, respectively. The rates of nerve conduction abnormalities are tabulated in **Table 3**. The most common peroneal abnormality was mean F-wave latency. The sural nerve DSL and SNAP had similar abnormality rates. Based on the case definition, DPN was identified in 52.6% of the encounters (DPN group, see **Table 3**). Neuropathy was *not* identified in 19.3% of the encounters (normal group, see **Table 3**). In the remaining encounters, abnormalities were limited to

Table 1.
Study Population Demographic Characteristics

Age range	% of total	Female (%)	Height (SD) (cm)	Weight (SD) (kg)	BMI (SD) (kg/m^2)
< 30	0.8	58.2	169.6 (10.8)	87.9 (27.5)	30.6 (9.3)
30–39	3.1	54.2	169.7 (10.9)	98.9 (27.4)	34.3 (9.1)
40–49	9.6	50.5	170.2 (10.8)	100.5 (25.3)	34.6 (8.2)
50–59	20.8	51.1	169.5 (10.7)	99.5 (23.7)	34.6 (7.7)
60–69	28.2	51.6	168.4 (10.8)	94.3 (21.6)	33.2 (6.9)
≥ 70	37.4	54.7	166.3 (10.8)	84.0 (18.3)	30.4 (5.9)

sural (14.8%, sural group, see **Table 3**) or peroneal (13.3%, peroneal group, see **Table 3**) nerves. Among encounters identified as normal, the peroneal mean F-wave latency was borderline in 8.2%. In contrast, in encounters with an abnormal sural response, 14.1% of the mean F-wave latencies were borderline. For studies with abnormal peroneal but normal sural responses, mean F-wave latency had the highest abnormal rate of 54.1%, followed by CMAP of 27.7% and DML of 8.1%.

Patients in the normal group had significantly different demographic characteristics ($p < 0.01$, two sample t test) than those with DPN. Among the former group, 66.6% were female, the mean age was 60.6 (±12.1) years, and the mean BMI was 31.8 (±6.5). In those patients with DPN by electrodiagnostic criteria, 44.2% were female, the mean age was 64.7 (±11.4), and the BMI was 32.8 (±7.5). The demographic characteristics for the normal and DPN groups were significantly different than those of the other two neuropathy groups ($p < 0.01$, two sample t test) with the following exceptions: BMI between normal and peroneal abnormality groups and age between sural abnormality and DPN groups were not statistically different.

Table 2.
Distribution of Participating Physicians and Usage Rate by Specialty

Physician specialty	Practices (%)	Diabetic studies (%)
Primary care	46.3	34.4
Internal medicine	34.8	31.3
Endocrinology	4.6	20.1
Podiatry	4.1	8.5
Rheumatology	3.2	1.7
Orthopedic surgery	2.4	0.7
Occupational medicine	0.6	0.6
Neurology	0.4	0.3
Pain management	1.2	0.2
All others	2.4	1.2

Table 3.
Prevalence of Neurodiagnostic Outcomes

Outcome	Rate (%)
Nerve conduction parameters (by nerve)	
Peroneal DML abnormal	14.0
Peroneal CMAP abnormal	32.5
Peroneal F-wave abnormal	33.6
Sural DSL abnormal	58.3
Sural SNAP abnormal	62.7
Neuropathy case definitions (by subject)	
Normal	19.3
DPN	52.6
Sural only	14.8
Peroneal only	13.3

Discussion

This study analyzed over 63,000 electrodiagnostic encounters by nearly 3500 physician practices over a 30-month period. We believe that this sample size and diversity significantly exceed prior studies of nerve conduction testing for DPN. Eighty-six percent of diabetes-related nerve conduction tests undertaken as part of this study involved physician practices whose self-identified specialty was primary care, internal medicine, or endocrinology (hereafter referred to as primary diabetes care physicians). Consistent with their central role in diabetes management, endocrinologists accounted for 20% of tests while representing fewer than 5% of the physician practices.

Although the locus of DPN management is primary diabetes care physician practices, nerve conduction studies have historically been performed by neurologists and physical medicine and rehabilitation (PM&R) physicians. Nevertheless, in a commercial insurance claims analysis of nerve conduction procedures, Dillingham and colleagues[19] showed that, in 1998, up to 25% of physician-supervised studies were performed by other physician specialties. In recent years, scientific advances have further enabled broad physician use of nerve conduction studies.[15] Similar to the use of other diagnostic procedures previously performed by selective specialists,[20] the use of nerve conduction studies performed by primary diabetes care and other physicians has been debated.[21] Studies demonstrating the clinical accuracy and utility of nerve conduction study procedures when performed by primary care physicians, internal medicine specialists, and orthopedic surgeons have been published.[14,16,22,23]

An important measure of the value of a diagnostic test is the diversity of diagnostic outcomes. It is intuitively clear that a test yielding the same reading in most encounters within a group is not informative because the diagnostic encounter is unlikely to result in differentiated treatment. Conversely, if a variety of diagnostic outcomes occur, then the test results partition the group into

subgroups that may benefit from different interventions. In this study, DPN was identified in 52.6% of patients; in another 19.3% of patients the electrodiagnostic encounter yielded normal results. Therefore, in 71.9% of the patients evaluated, the specific diagnostic question of whether or not the patient had DPN was addressed by the nerve conduction study. Evidence-based criteria for distal symmetric polyneuropathy,[18] in conjunction with the purpose of electrodiagnostic encounters (to assess diabetic neuropathy), were used to define DPN. This high DPN rate suggests that pretest patient selection led to clinically relevant electrodiagnostic encounters. In an additional 14.8% of encounters, the sural response was abnormal with normal peroneal nerve conduction. Although these study results did not meet the evidence-based definition of DPN, they may indicate early DPN.[24] This likelihood was supported by the finding that peroneal F-waves were nearly twice as likely to be borderline in this cohort as compared to the normal cohort. In 13.3% of the tests, peroneal nerve abnormalities were identified without concomitant DPN based on a normal sural nerve response. In these patients, the most common abnormality was a prolonged mean F-wave latency (54.1%). This finding is strongly associated with lumbosacral radiculopathy.[25–27] Prior studies have shown that lumbosacral radiculopathy involving the L5 or S1 roots was a common alternative diagnosis when a distal symmetrical polyneuropathy was suspected.[28–30] These patients might benefit from further clinical evaluation and diagnostic testing, including magnetic resonance imaging.

The clinical purpose of the electrodiagnostic encounters in this study was to evaluate polyneuropathy in patients with diabetes, and therefore the pretest diagnosis can be inferred to be DPN in most cases. In 32.6% of the encounters the test suggested a different posttest diagnosis of normal, lumbosacral radiculopathy, or another focal lower extremity neuropathy (e.g., peroneal neuropathy at the fibular head). This result was similar to the rate at which referral to traditional electromyography laboratories changed the referral diagnosis of polyneuropathy. Cho and colleagues[29] reported that in patients with the typical clinical characteristics of distal symmetrical polyneuropathy, electrodiagnostic consultation led to an alternative diagnosis in about 30% of cases. Kothari and colleagues[28] reported a rate of 42.9% among referrals for all polyneuropathy types. Among the 67.4% of encounters in which DPN was confirmed or suggested in the current study, abnormalities ranged from isolated sural abnormalities to low or absent motor responses. This spectrum of findings would be expected to impact therapeutic decisions,[24] reenforce patient self-management,[31] and stratify the risk of neuropathic complications such as foot ulcers[32] and risk of falls.[33]

In this study, patients evaluated for DPN by nerve conduction studies were slightly obese (mean BMI 32.6) and older (mean age 63.4). These demographic features are strongly associated with a higher risk of diabetes[34] and DPN.[35] In fact, high rates of nerve conduction abnormalities were observed in all nerves. These demographic and electrophysiological characteristics suggest that these nerve conduction tests were applied to patients from the appropriate demographic subgroups.

The prevalence of DPN in this study was comparable to levels obtained by academic electromyography laboratories.[36–38] Based on a 1998 health insurance claims analysis, Dillingham and colleagues[19] suggested that primary care physicians were significantly less likely than neuromuscular specialists to identify DPN on electrodiagnostic testing. However, the rate of DPN identified in this study (52.6% by case definition and 13.3% based on sural abnormality only) was considerably higher than reported by Dillingham *et al*.[19] In that study, the rate of DPN was approximately 12% in providers identified as neurologists or PM&R physicians. Similar rates were observed for osteopathic physicians, and a lower rate of approximately 8% was found for primary care and internal medicine physicians. The reason for the low DPN rates reported by Dillingham *et al*.[19] is unclear but may relate to the commercial claims data source, the younger age (mean 51 years) of the study group, and a polyneuropathy definition based on *International Classification of Diseases, Ninth Revision, Clinical Modification* codes rather than directly on electrophysiology.

The aforementioned conclusions from the nerve conduction assessments evaluated in this study were predicated on an assumption of instrument accuracy in measuring peroneal and sural nerve conduction and in detecting DPN. The validity of these nerve conduction measurements has been confirmed by correlations to electromyography laboratories[17,39] that ranged from 0.7 to 0.95 in blinded comparisons. These correlation coefficients were comparable to interexaminer correlation among board-certified electromyographers.[40,41] In a study meeting class I evidence-based criteria, the positive and negative likelihood ratios for detecting DPN were approximately 5 and 0.1, respectively.[17] These likelihood ratios represented clinically meaningful changes from pretest to posttest disease probability in terms of both ruling in and ruling out DPN.

This study had several limitations. First, data from a single nerve conduction registry, associated with a specific electrodiagnostic instrument, were analyzed. This particular instrument was widely used within some physician specialties (e.g., endocrinology) and less so within others (e.g., neurology). This adoption pattern would impact the usage distribution provided in **Table 2**. Second, studies identified as normal or DPN were defined as diagnostically specific, although subsequent clinical outcomes were not measured. However, DPN is a well-defined neurophysiological entity with an associated intervention plan. Third, this study did not evaluate clinical interpretation of nerve conduction data. There is no "gold standard" for neurophysiological diagnosis, as subjectivity and bias lead to limited interexaminer interpretation agreement even among physicians regarded as experts.[40,42,43] Long-term clinical outcomes such as glycemic control, pain scores, foot ulcers, amputations, and patient satisfaction could be used to evaluate the quality of diagnostic interpretations. However, to the extent that historical providers of this service represent a performance benchmark, such outcomes have not been evaluated for electrodiagnostic testing by neurologists and PM&R physicians.[28,44] This study has several implications for clinical practice. First, about one-third of patients with diabetes and presumed DPN may not have a large fiber polyneuropathy or may have focal pathology such as lumbosacral radiculopathy. Performing NCS at the point of service would identify these patients, who would then be subjected to a different evaluation and treatment plan. Second, a wide spectrum of nerve conduction abnormalities was identified in patients with DPN. This quantitative information could be used to risk stratify patients for the near term likelihood of foot ulcers[32] and other complications of DPN. Finally, many patients with diabetes are quantitatively oriented as a result of blood glucose monitoring. Providing these patients with clear and deterministic NCS feedback may help motivate self-management behavior, including glucose control and weight loss.

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Disclosure:

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