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TECHNICAL NOTE

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Importance of Electromyography and the Electrophysiological Severity Scale in Forensic Reports

ABSTRACT: Forensic reports on traumatic peripheral nerve injuries include dysfunction degrees of extremities, which are arranged according to the Turkish Penalty Code. The aim of this study is to discuss the role and importance of electromyography while preparing forensic reports in the cases of traumatic peripheral nerve injuries and the usefulness of scoring systems.A modified global scale, recommended by Mondelli et al., was used to assess the electrophysiological impairment of each peripheral nerve.Forensic reports of 106 patients, reported between 2002 and 2004, were evaluated. Thirty-four percent of the cases were reported as "total loss of function," 41.5% were reported as "functional disability," and there were no dysfunctions in the other cases in forensic reports that were prepared based on Council of Social Insurance Regulations of Health Processes and Guide prepared by the Council of Forensic Medicine and profession associations of forensic medicine. When we rearranged these forensic reports based on the electrophysiological severity scale (ESS), it was clearly found that all of the score 2 cases and 86.7% of the score 3 cases corresponded to "functional disability" and 91.4% of the score 4 cases correspond to "total loss of function." We found a significant correlation between the ESS and functional evaluation in peripheral nerve injury cases. Evaluation of functional disabilities in peripheral nerve injuries with the ESS represents a standardized and objective method used for forensic reports.

KEYWORDS: forensic science, forensic reports, electromyography, peripheral nerve injury, electrophysiological severity scale

Peripheral nerves could become damaged and may result in dysfunction of the extremities, due to blunt, sharp, or burst injuries. The nerves most likely to be injured are radial, ulnar, and median nerves in the upper extremities, and peroneal, tibial, and femoral nerves in the lower extremities (1–11).

Forensic specialists' legal reports, which determine the total harm caused to the victim, have an important role in the Turkish justice system. In other words, the forensic report determines the penalty of the accused indirectly. Forensic reports on traumatic peripheral nerve injuries include dysfunction degrees of the extremities, which are arranged according to the Turkish Penal Code. To prepare the forensic reports, the total improvement and the permanency of the disability need to be observed. After that, the degree of anatomic loss and functional disability of the extremities are determined according to the Council of Social Insurance Regulations of Health Processes and Guide, prepared by the Council of Forensic Medicine and profession associations of forensic medicine. If the degree of disability is between 10% and 50% it is reported as a "functional disability" and if it is over 50% it is reported as "total loss of function." In the 87th and 89th article of the Turkish Penal Code, it is described that if an injury results in "functional disability," the penalty of the accused is doubled and if it results in "total loss of function," the penalty of accused is tripled in intentional injuries. The penalty is increased by half in the case of "functional disability" and it is doubled in "total loss of function" if the crime is committed by imprudence also (12–14). Despite its potential severe legal implications, "functional disability" and "total loss of function" are subjective determinations. We believe that these qualitative descriptions have to be based on objective criteria that include numerical parameters.

The aim of this study is to discuss the role and importance of electromyography (EMG) while preparing forensic reports in the cases of traumatic peripheral nerve injuries and the usefulness of scoring systems.

Method

One hundred and six patients were included in this study, who had been sent to the Mersin University Faculty of Medicine Department of Forensic Medicine by courts for legal reports concerned with "functional disability" and "total loss of function" between 2002 and 2004. Age, sex, types of traumas, injured nerves, electrophysiological severity scale (ESS) scores, and the results of legal reports for all patients were evaluated with SPSS 10.0 package program. Dispersion of neuropathies according to types of trauma, relations between ESS scores and types of trauma, and the results of legal reports are investigated.

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Electrophysiological Methods

All electrodiagnostic investigations were conducted by the same neurologist using Medelec synergy equipment and software (Oxford, U.K.). EMG laboratories were staffed by the neurophysiologist during the study period and the standardized electrophysiological methods recommended by Preston and Shapiro were used (15). Case inclusion criteria and determination of the site of nerve damage were based on a combination of clinical findings (patterns of weakness and sensory loss) and distribution of electromyographic alterations. Only the cases in which an electrophysiological study was performed 3–12 weeks after the onset of neuropathy were included in the study as abnormal spontaneous electromyographic activity might be overlooked in cases studied soon after the injury and also injured nerves would have recovered completely in cases studied after 12 weeks. If more than one electrophysiological study was performed, the results of the first applied EMG were selected as a benchmark. Then, the nerve conduction studies and standard needle EMG investigations were performed on the necessary muscles. The EMG was also applied to the other muscles of the related limb according to clinical findings in order to make a differential diagnosis. An electromyographic study includes investigation of abnormal spontaneous activity at rest (positive sharp waves, fibrillation potentials, complex repetitive discharge, and fasciculations), qualitative evaluation of motor unit action potentials, and recording of recruitment pattern at full effort. Skin temperature of the limb was kept constant above 32°C (15). Conduction parameters of patients were compared with those of an age-matched control population (24 healthy volunteers, 13 women and 11 men, mean age 30.2 years, range 16–65). Values more than two standard deviations below or above the mean of controls were considered to be abnormal for nerve conduction studies.

ESS

A modified global scale, recommended by Mondelli and collegues (16,17), was used to assess electrophysiological impairment of each peripheral nerve. This scale was based on changes in the following electrophysiological parameters: (1) motor nerve conduction velocity (MCV) across the site of nerve lesion; (2) percentage decrease in compound muscle action potential (CMAP) amplitude between two successive points of stimulation across the site of nerve lesion; (3) needle EMG of peripheral nerve-innervated muscles; and (4) sensory nerve conduction velocity (SCV) and sensory action potential (SAP) amplitude of sensory nerve (see Table 1). The total electrophysiological score was the sum of all scores in each electrophysiological domain in cases with peripheral neuropathy of the main trunk. A higher score of the nerve represents severe neuropathy. The mean score of the whole subgroups represented the ESS in our study. The basic ESS does not include needle EMG of peripheral nerve-innervated muscles; it is incapable of evaluating reinnervation of damaged nerves. We modified the scale by adding needle EMG of peripheral nerve-innervated muscles to the existing parameters and this provides confirmation of MCV data, and provides important data about reinnervation of damaged nerves.

Procedure of Preparation of Forensic Reports

Before EMG application, each patient is examined by a forensic specialist and a neurologist. Recovery is followed up with repeated EMGs and neurological examinations. To monitor total improvement and to observe whether disabilities reach an irreversible state, a time period of 18 months is required. After that, the degree of anatomic loss and functional disability of the extremities are determined according to the Council of Social Security Regulations of Health Processes and Guide, prepared by the Council of Forensic Medicine and profession associations of forensic medicine. If the degree of disability is between 10% and 50% it is reported as a "functional disability," and degrees over 50% are reported as "total loss of function" (12,13).

Results

Forensic reports of 106 patients, reported between 2002 and 2004, were evaluated. 73% ($n = 77$) of the patients were male, 27% ($n = 29$) were females, and the average age was 33.5 ± 13.36 (range: 18–75). 44.3% ($n = 47$) of the cases were sharp injuries, 49.1% ($n = 52$) were blunt injuries, and 6.6% ($n = 7$) were gunshot injuries. Traffic accidents ($n = 27$), falls ($n = 14$), and beating ($n = 11$) were the most common types of blunt trauma.

The upper extremities were injured in 94 cases (88.7%) and the lower extremities were injured in 12 cases (11.3%). Seventy-three cases (68.9%) had mononeuropathy and 33 (31.1%) cases had polineuropathy. In the mononeuropathy group, the frequently injured nerves were the ulnar nerve with 23 cases, the radial nerve with 22 cases, and the median nerve with 17 cases. The most commonly injured nerve groups were the median–ulnar nerves in 15 cases and the median–ulnar–radial nerves in nine cases in the polineuropathy group. When the injured nerves were evaluated with respect to the type of trauma, the frequently injured nerves were radial nerves in the blunt trauma group, the ulnar and the median nerves in the sharp injury group, and the median–ulnar,

TABLE 1—*Electrophysiological severity scale.*

Score	EMG*	MCV*	CMAP* (amp)	SCV and SAP
0	Normal	Normal	Normal (<20%)	Normal
1	Moderately reduced pattern at full effort with or without denervation activity at rest	Reduced by <25% with respect to lower limits	>20%, <50%	Reduced SAP amplitude with respect to healthy side
2	Severely reduced pattern at full effort	Reduced by >25% with respect to lower limits	>50%	Absolute SAP amplitude reduced, normal SCV
3	Very severely reduced pattern at full effort (single oscillation)	Absence of CMAP	Absence of CMAP	SCV and SAP amplitude reduced
4	Absence of voluntary activity			Absence of SAP

The EMG score is the mean of EMG scores of affected peripheral muscles.

MCV, motor conduction velocity; CMAP, compound muscle action potentials (motor amplitude); SCV, sensory conduction velocity; SAP, sensory action potential.

TABLE 2—*Injured nerves according to the types of trauma.*

Nerve	Blunt	Sharp	Burst	Total
Mononeuropathy				
Ulnar	7	16	—	23
Radial	15	7	—	22
Median	4	12	1	17
Axiller	1	—	—	1
Peroneal	4	2		6
Posterior tibial	1	1	—	2
Femoral	—	1	—	1
Supra scapular	1	—	—	1
Mononeuropathy total				73 (68.9%)
Polineuropathy				
Median–ulnar	8	5	2	15
Median–radial	—	1	—	1
Radial–ulnar	1	1	—	2
Median–ulnar–radial	6	1	2	9
Musculocoutaneus–axillar	1	—	—	1
Peroneal–posterior tibial	2	—	1	3
Ulnar–Peroneal–posterior tibial	—	—	1	1
Radial–ulnar–peroneal–posterior tibial	1	—	—	1
Polineuropathy total				33 (31.1%)
Total	52	47	7	106

median–ulnar–radial polineuropathies in the gunshot injury group (Table 2).

Thirty-four percent of the cases ($n = 36$) were reported as "total loss of function," 41.5% ($n = 44$) were reported as "functional disability" and there was no dysfunction in other cases in forensic reports that were prepared based on the Council of Social Insurance Regulations of Health Processes and Guide which were prepared by Council of Forensic Medicine and profession associations of forensic medicine. When we rearranged these forensic reports based on the ESS, it was clearly found that all of the score 2 cases and 86.7% of the score 3 cases corresponded to "functional disability" and 91.4% of the score 4 cases correspond to "total loss of function." There was a significant correlation between the ESS scores and the results of forensic reports when the Spearman rank correlation analysis was applied (r: 0.312 and p: 0.001) (Table 3).

Discussion

As they take more places in active life, business and traffic, peripheral nerve injuries are observed more frequently in young males. The results of our study showed similarities to previously studied cases, in terms of sex, average age, type of trauma, affected extremity, and injured nerves (2,4,6,9,18–22).

Peripheral nerve injuries are mostly caused by trauma reasons, and rarely to otherwise. Mondelli et al. state that, 64 of 91 radial mononeuropathy patients have a traumatic etiology (16,17).

Traffic accidents, falling, work accidents, sharp injuries, gunshot injuries, and burst injuries are common causes of traumatic peripheral nerve neuropathies (1–3,5,7,8,10,19,20). In our study, 44.3% ($n = 47$) of the cases were sharp injuries, 49.1% ($n = 52$) were blunt injuries, and 6.6% ($n = 7$) were gunshot injuries. The range of traumas is quite similar to some other studies.

It is stated that ulnar and median nerves are frequently injured by sharp instruments, and peroneal and ischiadicus nerves are frequently injured by gunshot. Sixteen of 23 ulnar nerve injuries were caused by a sharp instrument in our study (1,2,5,6,8,10,19,23).

A forensic report on peripheral nerve lesions is prepared when there is complete recovery of the nerves and the lesion is permanent as per neurological examination, ROM, and EMG findings of a neurologist in our country. As per our studies, it was observed that there is a widespread usage of EMG data including defining the level of, regeneration, and healing schedule of the peripheral nerve lesions, monitoring surgical efficacy, classification of the injuries from scaled EMG data (5,7,19,20,23–25), and in addition, evaluation and reporting of forensic cases in our country.

On the other hand, while EMG is used, no scoring method is implemented during the process of defining and reporting the level of traumatic peripheral nerve injuries. No study was found in the literature on the usage of EMG with scoring for preparing forensic reports.

The scale prepared by Mondelli et al., which uses data of MCV, CMAP, SCV, SAP, and classifies loss of nerve conduction as score 0: normal, score 1: Moderately reduced, score 2: Severely reduced, score 3: Very severely reduced, and score 4: Absence of voluntary activity, also makes the evaluation of EMG in neuropathies easy (16,17) (Table 1).

We believe that, while being a difficult and complex method for forensic specialists, by evaluating MCV, CMAP, SCV, SAP included in EMG, and converting them into the ESS will ease the understandability of EMG (13–15).

Thirty-four percent of the cases ($n = 36$) were reported as "total loss of function," 41.5% ($n = 44$) were reported as "functional disability," and there was no dysfunction in the other 26 cases (24.5%). When we rearranged these forensic reports based on the ESS, it was clearly found that all of the score 2 cases and 86.7% of the score 3 cases corresponded to a "functional disability" and 91.4% of the score 4 cases corresponded to "total loss of function." We found a significant correlation between the ESS and functional evaluation in peripheral nerve injury cases (Table 3). Therefore, according to the EMG scale, score 0 and 1 cases can be classified as "normal," score 2 and 3 cases as "functional disability," and score 4 cases as "total loss of function." Although "functional disability" and "total loss of function" are subjective determinations, using the ESS and its numerical parameters based on EMG will increase the objectivity of these qualitative descriptions in forensic reports. Evaluation of functional disabilities in

TABLE 3—*Correlation between ESS scores and results of forensic reports.*

ESS scores\forensic reports	Normal	Functional Disability	Total Loss of Function	Total	
0	20	—	—	20 (18.9%)	$p = 0.001$ $R = 0.312$
1	6	—	—	6 (5.7%)	
2	—	15	—	15 (14.2%)	
3	—	26	4	30 (28.3%)	
4	—	3	32	35 (33%)	
Total	26 (24.5%)	44 (41.5%)	36 (34%)	106	

ESS, electrophysiological severity scale.

peripheral nerve injuries with the ESS represents a standardized and objective method used for preparing forensic reports.

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