The effects of changing body posture on the peripheral nerves in normal subjects and diabetic patients

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Abstract
Thirty nine diabetic patients, of both insulin dependent and noninsulin dependent types, and thirty four age and sex matched control subjects were included in this study in an attempt to clarify the effect of changing posture on the peripheral nerves in both groups and to clarify the effect of diabetes on the peripheral nerve by using electromyography.
Peripheral nerve dysfunction was evaluated by clinical examination, and electrophysiological testing of the somatosensory and autonomic peripheral nerves in supine and standing position. Sensory responses, motor responses and the minimal F-wave latency were recorded from the right and left ulnar nerves in supine and standing position.
The diabetic group show significant reduction in the sensory and motor amplitude and nerve conduction velocity with a significant prolongation of the motor inter-latency minimal F-wave latency in comparison with the control group. Abnormal reduction of the sensory and motor NCV was significantly correlated to the severity and duration of hyperglycemia. Also there is a significant reduction in the sensory and motor amplitude of diabetic patients on standing from supine position (more in sensory), which occur also in control subjects but in less frequency.
Lastly, we conclude that electrophysiological assessment of the function of the peripheral nerves is very essential for the diagnosis of the peripheral neuropathy that was commonly encountered in diabetes. Also, we found that both sensory and motor fibers are affected and both segments of the nerve were involved, although the distal more than the proximal. The underlying mechanisms were suggested to be a mixed process of axonal degeneration and demyelination, and most the changes were chronic.
Also, we found that both motor and sensory nerve fibers were affected by changing posture from supine to standing position.
Introduction

Conduction in Peripheral Nerve Generation and Propagation of the Action Potential

The nerve cells are excitable cells that are capable of self generation of electrochemical impulses at their membranes (Guyton and Hall, 2006). Action potential is also called impulse which is the rapid changes in the membrane potential that spread rapidly along the nerve fiber membrane. Each action potential begins with a sudden change from the normal resting negative membrane potential to a positive potential and then ends with an almost equally rapid change back to the negative potential. To conduct a nerve signal, the action potential moves along the nerve fiber until it comes to the fibers’ end (Guyton and Hall, 2006).

Factors affecting nerve conduction

Endogenous factors:
Nerve myelin and diameter are the most important, that conduction is faster in myelinated fibers (Kimura, 2001), because action potentials are formed quickly at each successive node of Ranvier instead of being propagated more slowly through every part of the axon's membrane (Seeley et al., 1998). Myelinated fibers can conduct action potential up to 50 times faster than the fastest unmyelinated fibers (Ganong, 2005). The conduction velocity increases approximately with the fiber diameter in myelinated nerve fibers and approximately with the square root of fiber diameter in unmyelinated nerve fibers (Guyton and Hall, 2000). The other factor is the internodal length of the myelinated fibers "the longitudinal resistance of the axoplasm" which is one of the factors that affect the time required for a local current to excite the next node. So, for rapid conduction the internodal distance must be great enough to maximize the jump of the action potential, while at the same time small enough to minimize the loss of current through the internodal membrane. Typically the internodal distance and the conduction time are about 1 mm and 20 μsec, respectively; the conduction velocity would then be 50 m/sec (Kimura, 2001).

Exogenous factors:
The temperature is one of the factors that affect nerve conduction, lower temperature slow down impulse propagation while at the same time augmenting the amplitude of nerve and muscle potentials, as demonstrated in the squid axon, and in human studies. The age also affect the conduction velocity, nerve conduction velocities increase rapidly as the process of myelination advances from roughly half the the adult value in full-term infants to the adult range at age 3-5 years. Conduction velocities of slower fibers also show a similar time course of maturation. Premature infants have even slower conduction velocities. Fetal maturation may alter peripheral nerve function by influencing myelin formation (Kimura, 2001). Conduction velocity begin to decline 30 - 40 years of age, but the values normally change by less than 10 m/s by the sixtieth year or even the eightieth year. One of the most important factors that affect nerve conduction is the pressure on the nerve. Minor or intermediate degrees of compression may result in a temporary conduction block in the fibers. This conduction block either reversed as soon as the pressure is released or might prolong to few weeks after the removal of the pressure (Kimura,
Also, the neurons are highly responsive to changes in pH of the surrounding interstitial fluids. Alkalosis greatly increases neuronal excitability, while acidosis greatly depresses neuronal excitability (Guyton and Hall, 2006).

Many drugs are known to increase the neuronal excitability such as caffeine, theophylline and strychnine. On the other hand, some drugs are known to decrease it such as most of the anesthetic drugs. Some drugs and chemicals, although by different mechanisms, interfere with the synaptic transmission, from these: cholinergic drugs and cholinesterase inhibitors increase the transmission, while anticholinergic drugs, curare and botulinum toxin will decrease the transmission (Laurence et al., 1997 and Katzung, 1998).

**Diabetic Neuropathy**

Diabetic neuropathy has been defined as a demonstrable nervous system disorder, either clinically evident or sub-clinical (proved by electrophysiological studies), that occurs in people with diabetes after exclusion of other causes. It includes manifestations in the somatic and/or autonomic parts of the peripheral nervous system. As with other complications of DM, the development of neuropathy correlates with the duration of diabetes and glycemic control; both myelinated and unmyelinated nerve fibers are lost. Because the clinical features of diabetic neuropathy are similar to those of other neuropathies, the diagnosis of diabetic neuropathy should be made only after other possible etiologies are excluded (Harrison, 2007).

**Diagnostic criteria of diabetic neuropathy**

At least two of five criteria are needed to establish the diagnosis of diabetic polyneuropathy (Dyck and Thomas, 1999):

1. The patient should have diabetes mellitus by the criteria of the National Diabetes Data Group (NDDG).
2. Diabetes mellitus has caused prolonged chronic hyperglycemia. Patient has predominantly distal sensory-motor polyneuropathy in lower extremities.
3. Diabetic retinopathy or nephropathy is approximately similar to polyneuropathy.
4. Other causes of sensory motor polyneuropathy are excluded.

**Pathophysiology of diabetic neuropathy**

The most accepted theories of the pathophysiological basis of diabetic neuropathy are:

**Metabolic theory:**

An association with the neuropathy attributed to chronic diabetes mellitus, the metabolic pathophysiology is poorly understood. Hyperglycemia is believed to produce a decrease in nerve myo-inositol and increased polyol pathway activity related to the increased conversion of glucose to sorbitol by aldose reductase. The reduced nerve myo-inositol leads to reduced \( \text{Na}^+/\text{K}^+ \)-ATPase activity and a resultant increase in intracellular \( \text{Na}^+ \). In isolation, the resultant mild depolarization of the resting membrane potential decreases conduction velocity independent of structural alteration. Additional changes, including inactivation of sodium channels and axoglial disjunction, may also contribute to conduction velocity abnormalities (Johnson’s Practical Electromyography, 2007). Finally, coexisting microvascular injury to the vasa nervorum and diminished production of nitrous oxide contribute to axonal ischemia and cellular damage, as may possible autoimmune damage mediated by antineuronal antibodies (Johnson’s Practical Electromyography, 2007).

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Vascular (ischemic/hypoxic) theory:
It is postulated that long standing hyperglycemia causes reduction in the delta-6 desaturation of linoleic acid. This may enhance the endoneurial vascular resistance, through reduction in the vasoactive prostanoids leading to reduction in nerve perfusion resulting in axonal degeneration and Schwann cell dysfunction (Cameron and Cotter, 1996, 1999, and 2000).

Other theories:
There are several theories that may explain the pathophysiology of diabetic neuropathy including:
• The Altered Neurotropic Support Theory (ANST); which claimed that as a result of impairment in production and transportation of the nerve growth factor, there is a reduction in the survival of sympathetic and small nerve fibers (Grandis et al., 2001).
• The lack of Laminin β2-gene expression may end in neuropathy; Laminin is a large heteromeric curariform lipoprotein composed of a large α chain and two smaller β chains; β1 and β2 that may play a protection role for nerve cell (Trone et al., 1995).
• The autoimmune theory; this theory considered the immunogenic alteration of endothelial capillary cell may cause neuropathy (Baba, 2001).

Electrodiagnostic assessment of diabetic neuropathy:
Electrophysiological techniques have the advantage of being the most objective, sensitive, specific, and reproducible methods for the detection of the nerve, muscle, and neuromuscular junction lesions as swell as functional impairment (Dyck, et al. 1997) even before being recognized by clinical examination (Ziegler, 1996).

Standard electrophysiological tests include:
Nerve conduction velocity (NCV), electromyography (EMG), and evoked potentials (somatosensory evoked potential (SEP), visual evoked potential (VEP), and auditory evoked potentials (AEP)), as well as H reflex test are simple conventional electrophysiological techniques.

Electrophysiological study of the peripheral nervous system
Nerve Conduction Studies:
Sensory Nerve Conduction Studies:
The sensory nerve conduction studies were initially demonstrated by Dawson and Scott in 1949 and were shown to be clinical value in 1958 by Gilliat and Sears. Sensory nerve action potentials (SNAP) are of much lower amplitude than are compound muscle action potentials and are sometimes below the level of noise and artifact in the recording. Averaging of multiple potentials is then required to record them reliably, particularly at proximal locations over the plexus or spinal cord (Aminoff, 1999). In recording sensory nerve action potentials, averaging can virtually eliminate the background noise up to 50 times but not 100 times the signal. Two main methods are used to determine the sensory nerve conduction study: - The orthodromic "by which the nerve is stimulated distally and the recording is done proximally from the nerve trunk”, and antidromic” by which the nerve is stimulated proximally and the recording is done distally” Recording with surface electrodes, the antidromic response is larger than the orthodromic since the digital nerves are nearer to the surface than nerves at the wrist (Kimura, 2001).
For routine clinical recording, surface electrodes provide adequate reproducible informations noninvasively. Some electromyographers prefer needle recording to improve the signal-to-noise ratio especially in assessing temporal dispersion (Kimura, 2001). Sensory neuropathy is a prominent component of diabetic neuropathy (Brain, Oxford Journals, 2004) and the sensory action potential is altered only after involvement of larger myelinated fibers, which is often a late event in patients with diabetes (Nature Clinical Practice Neurology, 2007).

**Motor Nerve Conduction studies**

Motor nerve conduction studies were first described for clinical use in 1948. Subsequent studies defined normal values and abnormalities seen in the clinical disorders, motor nerve conduction studies have expanded steadily since then (Aminoff, 1999). For motor nerve conduction studies, the nerve is stimulated at two or more points along the course of the nerve and recording muscle action potentials with a pair of surface electrodes: an active lead placed on the belly of the muscle and an indifferent (reference) lead placed on the tendon (Kimura, 2001). Increasing the stimulus further should result in no change in the size of the muscle potential. The use of 20 to 30 percent supramaximal intensity guarantees the activation of all of the nerve (Kimura, 2001).

Stimulation of a motor nerve and recording the depolarization of a muscle it supplies produces a compound muscle action potential (CMAP) also called M wave. Similarly, stimulation of a sensory nerve and recording the signal of the nerve depolarization wave from a different point along the nerve produces a sensory nerve action potential (SNAP) (Johnson Practical Electromyography, 2007).

The compound muscle action potentials are recorded using a pair of surface electrodes and by needle electrodes. The recorded response is simple biphasic potential with an initial large upward (negative) deflection followed by a smaller downward (positive) deflection. If a small positive potential precedes the negative peak, the recording electrode should be repositioned until the appropriate shape of the evoked potential is obtained (Kimura, 2001).

**The F-wave Study**

**Definition:** F-wave is a late muscle response that follows the direct motor potential (M-response), it results from the backfiring of antidromically activated motor neurons (anterior horn cells), which can be recorded with a supramaximal electrical stimulus from almost every skeletal muscle (Kimura, 2001).

Electrical stimulation of motor fibers results in an impulse that travels both orthodromically toward the muscle and antidromically toward the spinal cord. The short latency direct response from orthodromic conduction is called the M-wave, and the late response occurring after the M-wave is termed the F-wave (Kimura, 2001).

F wave is not a reflex, per se, in which the nerve potentials travels from the site of the stimulating electrode in the limb to the spinal cord and back to the limb in the same nerve that was stimulated (American Association of neuromuscular and Electrodagnostic medicine, 2007).

**Subjects Materials and Methods:**

Subjects: Two groups of human subjects were included in the present study. Electroneurographic tests were carried on the two groups, i.e. the control and the patient groups. Electrophysiological studies were performed in the Neurophysiology Units/Department of Physiology in Al-Sadr Teaching Hospital at Al-Najaf and Marjan Teaching Hospital at Hilla City.

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The control subjects: Thirty four healthy volunteers were included in this study (19 males and 15 females). The age of this group ranged between (19 and 70 years) with a mean of (37.53 ± 10.88) years. Their social status ranged between doctors, medical students, hospital working staff and other volunteers.

The subjects included in this study have the following criteria:

A. Non diabetic (FBS was <110 mg/dl (6.1 mmol/l)).
B. No evidence of neurological disease.

All of them were instructed and informed about the aim of the study and investigation procedures and their acceptance was taken.

The patients: Thirty nine patients whom are a known cases of diabetes mellitus (DM) of both (insulin dependent and noninsulin dependent DM) of both sexes (males and females), their ages ranging between (21 and 70 years) with a mean of (47.9 ± 14.4) years. All those patients were referred to the unit of neurophysiology after being diagnosed by a specialist. All the patients were on treatment (oral hypoglycemic agents or insulin injection). Their disease duration ranges from 5 months to 25 years with a mean duration of (8.23) years. All of them have no history of alcoholism, renal or other metabolic diseases identified on a medical questionnaire. As the control subjects, they were informed about the aim of the study and investigation procedure and their acceptance were taken.

After full medical history and clinical examination all the subjects underwent electrophysiological study.

Methods: All subjects were investigated by the following electrophysiological studies:

(a) Sensory nerve conduction of right and left ulnar nerves.
(b) Motor nerve conduction and F-wave studies of right and left ulnar nerves.

All these electrophysiological studies were performed in both supine and standing positions for both patients and control subjects.

The test procedure was explained in brief for each subject in order to alleviate any fear, anxiety, or apprehension that may be present in the subject. All the subjects were examined in the morning, at a room temperature of 25 to 28 °C, and they were kept in this room for at least 15 minutes before being electrophysiologically examined, and their skin temperature ranged between 30 and 34 °C (measured by a thermometer inserted between the index and the middle finger).

Nerve conduction velocity study: For nerve conduction velocity study the following instruments were used:

a. Recording machine.
b. Electrodes.

The EMG machine: Micromed Systemplus digital system was used for all the electrophysiological analysis of sensory, motor nerve conduction parameters and sympathetic skin response. The Micromed Systemplus is four-channel equipment which is designed to have a wide range of applications in the field of electrophysiological testing and clinical neurophysiology. This system includes two sets of four channels preamplifiers and two isolated stimulators with separate jacks (A and B).
A group of controls in the keyboard of the system is used for setting the stimulus intensity (1-99 MA), duration (0.05-1 msec), polarity (positive, negative, and alternate), and frequency of its presentation (0.1-100 Hz), these can also be set by using the mouse of the system. The evoked responses can be displayed on the monitor, on which the four channels can be displayed at the same time. The results are printed in laser shoot printer associated with the machine on A4 type papers to obtain permanent recording of the displayed signals, and a copy of the results of each examined subject is stored in the memory of the system to be ready if we need it later on. The machine also contains an audioamplifier, the audioamplification during needle examination helps in the recognition of much potential by their characteristic sounds.

During nerve conduction studies the auditory monitor help to localize the site of stimulation of the nerves. Auditory feedback of muscle activity can be used to help patients to relax. A group of controls in the keyboard is used to adjust the amplification (sensitivity), sweep speed (time scale), and the various measurement of the displayed signals, which can also be adjusted by using the mouse of the system.

**Electrodes:**

**A. Grounding Electrode:** A Velcro ribbon strapped surface-grounding electrode (Micromed) was used to protect the subject against electrical hazard and to reduce artifacts and interference. The electrode was soaked in normal saline before use, to ensure good electrical conduction.

**B. Stimulating Electrodes:** A bipolar surface stimulating electrode (Micromed) was used to stimulate motor nerves through the skin. The electrode consists of two felt tips mounted in the stainless steel holders in a plastic frame. Center to center between the felt tips is 23 mm gild each felt tip diameter is 6 mm. The felt tips were soaked in normal saline before use to ensure good conduction. They were applied manually on the skin over the nerve to be tested. The cathode of the stimulation electrode was indicated by the sign of minus (-), and the anode was indicated by the sign of plus (+).

**C. Recording Electrodes:** Different recording electrodes were used for different purposes as follows:

1. **Surface electrodes:**
   a) For sensory conduction studies from the ulnar nerve: A pair of ring finger electrodes (Micromed) was used to record the antidromic responses from the skin of the finger innervated by the nerve to be tested. Each electrode is formed of a metallic ring. They were connected to the amplifier socket by an electrode cable (Micromed loop connecting cable). The red marked ring indicates the active recording electrode while the white marked ring indicates the reference electrode. Before application of these electrodes, the skin was cleaned by spirit and each electrode was soaked in normal saline to ensure good electrical conduction.

b) For motor conduction studies and F-wave recording from the ulnar nerve: A pair of circular plates of silver chloride (7mm in diameter) (Micromed surface recording electrode) were used as recording electrodes (called surface bipolar electrodes) for studying the evoked compound muscle action potential (CMAP) parameters (amplitude, conduction velocity, duration and area) and to detect any evidence of conduction block and abnormal temporal dispersion. The surface bipolar electrodes were fastened to the skin with sticking plaster and an electrode paste (Micromed -paste) was used to ensure good electrical contact between skin and electrodes. These surface electrodes were connected to the amplifier by an electrode cable (Micromed loop connecting cable). Before application of these electrodes, the skin was cleaned by spirit and each electrode was soaked in normal saline to ensure good electrical conduction.
The recording procedure and measurements: Motor nerve conduction and F-wave study of the ulnar nerve and antidromic sensory nerve conduction study of the ulnar nerve were conducted on both sides (right and left) of the body in both supine and standing position. The sympathetic skin response was recorded from both sides (right and left) upper and lower limbs.

Sensory nerve conduction studies: A. In supine position: While the subjects lying in supine position for 3-5 minutes; we perform the sensory nerve conduction study for right and left ulnar nerves in all subjects. The sensory nerve conduction study program incorporated in the EMG system was used for recording and analysis of the compound sensory nerve action potential. The electromyographic setting was:

- Frequency: 20/2000 Hz
- Sweep speed: 100 µsec
- Sensitivity: 10-20 µV/Div
- Stimulus intensity: 0-20 mA

The stimulus intensity was increased gradually until we get a maximum response (up to 20 mA) without an overlap with motor nerve action potential. Ten responses were averaged. The averaged sensory nerve action potential (SNAP) latency (measured as the time from the beginning of the stimulus artifact to the first deflection of the SNAP from the baseline), duration and peak to peak amplitude was analyzed automatically. By dividing the latency (msec) by the distance between the stimulating and the active electrode (measured by a flexible tape measure), we obtain the sensory nerve conduction velocity (Kimura, 2001).

The parameters studied in sensory conduction include:

1. The sensory latency.
2. Amplitude.
3. Sensory nerve conduction velocity.

\[
\text{SNCV (m/sec)} = \frac{\text{The distance (d) (mm)}}{\text{Time (t) (msec)}} \quad (\text{Ludin, 1990})
\]

Meaningful comparisons of the sensory latency require strict standardization of recording electrodes was standardized for sensory studies (ulnar nerve, 12cm). The sites of the electrodes for sensory nerve conduction studies for the tested nerves were as the following:

- The Ulnar Nerve:
  - Stimulation: Stimulation was applied with finger surface electrodes, around the fifth digit with the cathode (red marked ring) at the base of the digit. Ground: The ground electrode was placed between the stimulating and recording electrodes.
  - Recording: the recording electrode was placed over the ulnar nerve at the wrist, just radial to the flexor carpi ulnaris. The cathode was placed distally, 12cm from the active ring electrode.

B. In standing position: After standing from the supine position for 3-5 minutes, the same procedure of recording as in supine position was performed in standing position for right and left ulnar nerves in all subjects.

Motor Nerve Conduction studies:
A. In supine position: While the subjects lying in supine position on the couch for 3-5 minutes; we perform the motor nerve conduction study for right and left ulnar nerves in all subjects. The motor nerve conduction study program incorporated in the EMG system was used for recording and analysis of the compound muscle action potential evoked nerve stimulation. The stimulus intensity was increased gradually to a level above which the evoked potential
The distal motor latency (DML) is the time measured from the onset of the stimulus artifact to the beginning of the initial deflection from the baseline. By stimulating the nerve at two different sites the motor nerve conduction velocity (MNCV) can be calculated:

\[
\text{MNCV (m/sec)} = \frac{\text{Distance between two stimulating sites}}{\text{Conduction time (Conduction time = Difference between latencies in msec)}}
\]

A bipolar surface simulating electrode (Micromed surface stimulating electrode) was used for stimulating the motor nerves. The parameters studied in motor conduction study include:

1. Distal motor latency.
3. Duration.
4. Amplitude.
5. Area.
6. F-wave minimal latency.

For studying these parameters a pair of surface electrodes was used as recording electrodes.

The electromyographic setting was:

- Frequency: 20/5000 Hz
- Sweep speed: 50 msec/Division
- Sensitivity: 1-5 mV/Division
- Stimulus intensity: 0-99 mA

To establish the best diagnostic index of conduction block and abnormal temporal dispersion, the compound muscle action potentials (CMAP) were recorded using a pair of surface electrodes. The active electrode was placed on the belly of the muscles and the difference electrode on the tendon (belly-tendon recording) for the respective thenar, hypothenar and extensor digitorum brevis muscles. The amplitude of the evoked compound muscle action potential was measured from peak to peak in millivolts and the duration of the response was measured in milliseconds from the onset of the first negative to positive baseline crossing (Kimura, 2001).

The sites of the electrodes for motor nerve conduction studies of the tested nerves were as the following:

**The Ulnar Nerve:**

- **Stimulation:** was performed at two sites using a bipolar surface stimulating electrode (Micromed surface stimulating electrode).

  - Distally: at the wrist, 8 cm proximal to the active recording electrode, and just over the flexor carpi ulnaris tendon with cathode apply more distally.
  - Proximally: at the elbow just distal to the ulnar groove.

- **Grounding:** The grounding electrode was placed between the stimulating and the recording electrodes.

- **Recording:** The active surface electrode was placed at the abductor digiti minimi, on a point midway between the distal wrist crease at the base of the fifth digit.

**The F-wave study:** F-responses were recorded from right and left abductor abductor digiti minimi muscles by stimulating the right and the left ulnar nerves at the wrist on supine and standing position.

**EMG machine** Micromed systemplus digital system was employed using the F-wave implemented program for F-response recording and analysis.
The Electrodes: In this test, the same grounding, stimulation and recording electrodes were used as for the ulnar nerve conduction velocity determination.

Procedure: The examination technique is practically the same as that used when examining the motor conduction velocity of the ulnar nerve and was performed in both supine and standing positions for all subjects.

In the clinical practice, however, the effect of anodal hyperpolarization mostly abates before the arrival of the propagating impulse with use of an ordinary stimulator having two poles separated by 2-3 cm thus; the reversal of the stimulator orientation provides no added advantage in the study of F-wave conduction. The intensity of the stimulating current was adjusted manually to evoke a maximal muscle (M) response. After that, the intensity was increased by 20-30% to ensure supramaximal stimulation.

The electromyographic setting was:
Frequency: 20/2000 Hz
Sweep speed: 100 msec / Division
Sensitivity: 500µV/Division
Stimulus intensity: 0-99 mA

These recording parameters automatically arranged and compress the simultaneously recorded M-to the initial portion of the tracing, thus the M-response and the F-wave were studied separately using different gain and time bases. F-wave latencies, measured from the stimulus artifact to the beginning of the evoked potential, vary by few milliseconds from one stimulus to the next. Hence, we displayed ten trials on a storage oscilloscope automatically shifting successive sweeps vertically (a function provided by Micromed Systemplus F-wave analysis program).

The clearly identified F-wave were recorded and automatically analyzed by the program for detecting the minimal F-wave latency.

Statistical analysis:
Using the Statistical Package for the Social Science (SPSS), the arithmetic mean and standard deviation of distribution of each of the parameters were calculated for all of the subjects. The data are presented as number, mean ± SD and as percentage of number of observations. The T-test program was used to get the significance level (P-value) for all of the patients’ parameters tested after being compared with that of the control group. The data are analyzed by using confidence interval as 95 ٪, simple correlation; taking p ≤ 0.05 as the lowest limit of significance

Results:
The Results of Nerve Conduction Study:
The sensory nerve conduction studies results:
The sensory conduction velocity, sensory amplitude and sensory latency were measured for right and left ulnar nerves in supine and standing position in diabetic patients, and their results were compared with that of the control group. These results and their level of significance are shown in table (3-4, 5, 6, and 7)
Table (1) Sensory NCS parameters of right ulnar nerve

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Control Subjects</th>
<th>Diabetic Patients</th>
<th>P1-P2 value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CV (m/sec)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supine</td>
<td>48.24 ± 5.67</td>
<td>48.99 ± 6.33</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Standing</td>
<td>45.92 ± 12.99</td>
<td>43.1 ± 12.13</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Amp. (µV)</td>
<td>26.49 ± 12.38</td>
<td>22.51 ± 11.47</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Lat. (msec)</td>
<td>2.36 ± 0.31</td>
<td>2.33 ± 0.44</td>
<td>&gt;0.05</td>
</tr>
</tbody>
</table>

In control subjects the sensory amplitude of the right ulnar nerve is significantly decreased on standing position.

Table (2) Sensory NCS parameters of right ulnar nerve

<table>
<thead>
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<td>2.33 ± 0.44</td>
<td>&gt;0.05</td>
</tr>
</tbody>
</table>

In supine position the sensory amplitude of diabetic patients is significantly lower than that of control subjects, with significant differences between the two P-values of the amplitude and conduction velocity.

Table (3) Sensory NCS parameters of left ulnar nerve

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Control Subjects</th>
<th>Diabetic Patients</th>
<th>P1-P2 value</th>
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</thead>
<tbody>
<tr>
<td>CV (m/sec)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supine</td>
<td>48.4 ± 6.72</td>
<td>48.69 ± 5.76</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Standing</td>
<td>45.02 ± 13.08</td>
<td>43.81 ± 12.44</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Amp. (µV)</td>
<td>27.71 ± 13.52</td>
<td>26.5 ± 10.05</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Lat. (msec)</td>
<td>2.36 ± 0.35</td>
<td>2.33 ± 0.27</td>
<td>&gt;0.05</td>
</tr>
</tbody>
</table>

In diabetic patients the sensory amplitude is significantly decreased in standing position.

Table (4) Sensory NCS parameters of left ulnar nerve

<table>
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</tr>
<tr>
<td>Amp. (µV)</td>
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<td>19.34 ± 13.77</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Lat. (msec)</td>
<td>2.36 ± 0.35</td>
<td>2.24 ± 0.72</td>
<td>&gt;0.05</td>
</tr>
</tbody>
</table>
In supine position the amplitude of diabetic patients is significantly lower than that of control subjects. In standing position the sensory amplitude and sensory conduction velocity are significantly lower in diabetic patients than that of control subjects. The results and the level of significance were shown in the figures (1-9).

P-Value for sensory conduction velocity was >0.05
P-Value for sensory amplitude was <0.05
P-Value for sensory latency was >0.05

Figure (1) Comparison between right ulnar nerve sensory parameters of control subjects in supine and standing position.

P-Value for sensory conduction velocity was >0.05
P-Value for sensory amplitude was >0.05
P-Value for sensory latency was >0.05
Figure (2) Comparison between left ulnar nerve sensory parameters of control subjects in supine and standing position.

P-Value for sensory conduction velocity was >0.05
P-Value for sensory amplitude was <0.0
P-Value for sensory latency was >0.05

Figure (3) Comparison between right ulnar nerve sensory parameters in control subjects and diabetic patients in supine position.

P-Value for sensory conduction velocity was >0.05
P-Value for sensory amplitude was <0.05
P-Value for sensory latency was >0.05
Figure (4) Comparison between left ulnar nerve sensory parameters in control subjects and diabetic patients in supine position.

P-Value for sensory conduction velocity was <0.05
P-Value for sensory amplitude was >0.05
P-Value for sensory latency was <0.05

Figure (5) Comparison between right ulnar nerve sensory parameters of diabetic patients in supine and standing position.

P-Value for sensory conduction velocity was >0.05
P-Value for sensory amplitude was <0.05
P-Value for sensory latency was >0.05
Figure (6) Comparison between left ulnar nerve sensory parameters of diabetic patients in supine and standing position.

<table>
<thead>
<tr>
<th>Means</th>
<th>Standing</th>
<th>Standing</th>
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<tr>
<td>Sensory CV</td>
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<td>Sensory latency</td>
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</tr>
</tbody>
</table>

P-Value for sensory conduction velocity was <0.05
P-Value for sensory amplitude was <0.
P-Value for sensory latency was >0.05

Figure (7) Comparison between right ulnar nerve sensory parameters in control subjects and diabetic patients in standing position.

<table>
<thead>
<tr>
<th>Means</th>
<th>Standing</th>
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<th>Standing</th>
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<td>Sensory latency</td>
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<td>Sensory latency</td>
</tr>
</tbody>
</table>

P-Value for sensory conduction velocity was <0.05
P-Value for sensory amplitude was <0.05
P-Value for sensory latency was >0.05

Figure (8) Comparison between left ulnar nerve sensory parameters in control subjects and diabetic patients in standing position.

The results of motor nerve conduction study:

The motor nerve conduction velocity, motor amplitude and motor inter latency were measured for right and left ulnar nerves in supine and standing position in diabetic patients, and their results were compared with that of the control subjects. The results and their level of significance are shown in table (5-9). For these nerves, the effect of changing posture (from supine to standing) on the motor nerve function of patients’ group and control subjects with their significance level are shown in the figures (3-13, 14, 17, and 18). The results of comparisons between the nerves of the same limbs for both control subjects and the diabetic patients with their significance level are shown in figures (3-15, 16, 19, and 20) (241)

In diabetic patients there is a significant decrease in the motor amplitude of right ulnar nerve on standing position, with a significant difference between the two P-values of the F-wave minimal latency.

The motor conduction velocity and the motor amplitude of diabetic patients are significantly lower than that of control subjects in both supine and standing position, and the F-wave minimal latency in diabetic patients is higher than that of control subjects in both supine and standing position, with significant difference between the two P-values of F-wave minimal latency.

No significant difference was seen.
Table (8) Motor NCS parameters of left ulnar nerve

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Control subjects</th>
<th>Diabetic Patients</th>
<th>P1-value</th>
<th>Control subjects</th>
<th>Diabetic Patients</th>
<th>P2-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CV (m/sec)</td>
<td>54.04 ± 5.4</td>
<td>49.44 ± 10.61</td>
<td>&lt;0.05</td>
<td>54.06 ± 7.13</td>
<td>49.44 ± 10.61</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Amp. (µV)</td>
<td>10.26 ± 2.27</td>
<td>7.25 ± 3.39</td>
<td>&lt;0.05</td>
<td>10.05 ± 2.14</td>
<td>7.25 ± 3.39</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Interlat. (msec)</td>
<td>4.67 ± 0.4</td>
<td>4.99 ± 0.94</td>
<td>&gt;0.05</td>
<td>4.71 ± 0.63</td>
<td>4.99 ± 0.94</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>F-wave min.lat. (msec)</td>
<td>24.45 ± 1.61</td>
<td>26.17 ± 2.03</td>
<td>&lt;0.05</td>
<td>24.04 ± 1.01</td>
<td>26.17 ± 2.03</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

The motor conduction velocity and the motor amplitude of diabetic patients are significantly lower than that of control subjects in both supine and standing position, and the F-wave minimal latency in diabetic patients is higher than that of control subjects in both supine and standing position.

The results and the level of significance are shown in the figures (9-16).

P-Value for motor conduction velocity was >0.05
P-Value for motor amplitude was >0.05
P-Value for motor interlatency was >0.05
P-Value for F-wave minimal latency >0.05
Figure (9) Comparison between right ulnar nerve motor parameters in control subjects in supine and standing position.

P-Value for motor conduction velocity was >0.05
P-Value for motor amplitude was >0.05
P-Value for motor latency was >0.05
P-value for F-wave minimal latency >0.05

Figure (10) Comparison between left ulnar nerve motor parameters in control subjects in supine and standing position.

P-Value for motor conduction velocity was <0.05
P-Value for motor amplitude was <0.05
P-Value for motor latency was >0.05
P-Value for F-wave minimal latency <0.05
Figure (11) Comparison between right ulnar nerve sensory parameters in control subjects and diabetic patients in supine position.

P-Value for motor conduction velocity was <0.05
P-Value for motor amplitude was <0.05
P-Value for motor interlatency was >0.05
P-Value for F-wave minimal latency < 0.05

Figure (12) Comparison between left ulnar nerve motor parameters in control subjects and diabetic patients in standing position.

P-Value for motor conduction velocity was >0.05
P-Value for motor amplitude was <0.05
P-Value for motor interlatency was >0.05
P-Value for F-wave minimal latency >0.05

Figure (13) Comparison between right ulnar nerve motor parameters in diabetic patients in supine and standing position.

- P-Value for motor conduction velocity was >0.05
- P-Value for motor amplitude was >0.05
- P-Value for motor interlatency was >0.05
- P-Value for F-wave minimal latency >0.05

Figure (14) Comparison between left ulnar nerve motor parameters in diabetic patients in supine and standing position.

- P-Value for motor conduction velocity was < 0.05
- P-Value for motor amplitude was < 0.05
- P-Value for motor interlatency was > 0.05
- P-Value for F-wave minimal latency < 0.05

(246)
Discussion

In this study these two categories are directly or indirectly investigated electrophysiologically with especial consideration of postural effects. In this study the control group is selected to be age and gender matched to the patient group, this is important to exclude the effect of these two factors on clinical and electrophysiological tests. In addition, there was no significant difference in the incidence of smoking habit and cardiovascular disease between the two groups. However, the incidence of hypertension was higher in the diabetic group subjects. The majority of the patients included in this study presented with mild to moderate neuropathic symptoms and signs that were generally absent in the control subjects. Moreover, significant correlation was observed between the clinical signs and symptoms and some of the electrophysiological parameters. The reduction of the NCV (sensory and motor) was more prominent in patients with more neuropathic symptoms indicating that this study is concerned with an established diabetic neuropathy that is related to axonal degeneration and/or demyelination rather than simple acute nerve function derangement (Dyck PJ, Giannini C, 1996). In regard to the electrophysiological parameters, the diabetic patients showed a significant reduction of sensory and motor nerve conduction velocities in the tested nerves (right and left ulnar nerve). With sensory affection more than the motor (some patients even have no sensory response). The reduction in the sensory and motor NCV was more prominent in patients with higher fasting blood sugar and longer disease duration. Many studies have also demonstrated that diabetic polyneuropathy appears to be related to the duration and degree of hyperglycemia (Dyck

A reduction in the amplitude of the sensory and motor responses was also noted in diabetic patients especially on standing position (which also occurs in the right ulnar nerve sensory amplitude in control subjects). This reduction in amplitude was enough to reach a statistically significant level. The amplitude of a compound muscle (or nerve) action potential is an expression of fiber density or fiber number per unit cross sectional area (Daube JR, 1999 and Kimura 2001). Selective loss of large fast conducting fibers results in a reduction of the response amplitude with some slowing of conduction, but the NCV is seldom reduced by more than 20-30% of the normal values. A more severe reduction of the NCV (more than 30-40 30 caused by demyelination (Daube JR, 1999 and Kimura 2001).

In this study we found that there is a significant reduction in the amplitude on standing position in sensory and motor (mainly sensory) divisions of right and left ulnar nerve in diabetic patients and control subjects (more in diabetic patients), and since the amplitude of the compound muscle action potential (CMAP) is a function of the number and size of nerve and muscle fibers “the number of the functioning axons in a nerve, and the amount of muscle still innervated“ (and for sensory nerve action potential is a function of the number of the functioning axons in the nerve) (Daube, 1999), we believe that this may give a clue that there are less functioning axons on standing position than supine position.

From the above observations it is reasonable to say that the reduction of the NCV in the diabetic patients is mostly due to axonal degeneration affecting preferentially the large, fast conducting fibers at least in early stages of the disease. With the progress of the diabetes, more nerve fibers are affected and loses their function involving the slow in addition to the fast conducting fibers and there might be demyelination and some sort of regeneration. In more diseased nerves, the waveform of the action potential may be significantly altered by increased temporal dispersion and the area under the curve becomes a better indicator of fiber density than the amplitude (Kimura 2001).

The minimal latency of the F-wave is used as a measure of the fastest conducting fibers along the entire length (proximal and distal segment) of the motor nerve (Kimura 2001). In order not to miss proximal nerve lesions, we measured the minimum F-wave latency in the ulnar nerve. In control subjects the minimum F-wave latencies were comparable to that obtained by other studies (Buschbacher RM, 1999 Ulnar nerve F-wave latencies recorded from the abductor digiti minimi abstract and Buschbacher RM, 1999 Peroneal nerveF-wave latencies recorded from the extensor digitorum brevis abstract). Diabetic patients underwent test showed a significant prolongation of the ulnar nerve minimum F-wave latency. The minimum F-wave latency has been widely used to detect diabetic polyneuropathy. It was reported to be highly sensitive and the most reproducible measure in the nerve conduction studies for the detection of peripheral polyneuropathy (Johnsen B, Fuglsang-Frederiksen A, 2000 and Kohara N, Kimura J, Kaji R, et al,2000). The prolonged Fmin latency and reduced NCVs in our diabetic patients reinforce each other to confirm the predominant affection of the large, fast conducting fibers at early stages of the disease process (neuropathy). There is no significant difference in F-wave minimal latency between supine and standing position.

Conclusion
1. There was as significant effect of changing posture from supine to standing on the peripheral nerve conduction (sensory and motor) parameters especially amplitude in both diabetic and control groups.
2. The severity of the peripheral neuropathy expressed by a reduction in the nerve conduction velocity is significantly related to the severity and duration of hyperglycemia in diabetic patients.
3. The abnormalities in NCV, minimal F-wave latency and amplitude suggest that peripheral neuropathy in the diabetic patients is mostly due to axonal degeneration affecting preferentially the large, heavily myelinated, fast conducting fibers.

REFERENCES