Saphenous nerve conduction in man¹

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At present, the most reliable methods for investigating sensory nerve conduction for diagnostic purposes involve the median and the ulnar nerves (Gilliatt and Sears, 1958; Buchthal and Rosenfalck, 1966). In the lower extremities, pure sensory conduction is, however, not easily studied. It has recently been shown that sensory potentials recorded in the posterior tibial and the fibular nerves at the ankle have a considerably lower amplitude than the sensory action potentials in the nerves of the arms and that an averaging computer is necessary to obtain accurate recordings (Mavor and Atcheson, 1966; Buchthal and Rosenfalck, 1966).

The difficulties mentioned in the study of the sensory conduction in the lower extremities are of great clinical disadvantage, since many polyneuropathies first give rise to sensory symptoms in the legs. It is, therefore, often important to be able to measure early changes of the sensory nerve in the legs, especially in cases with only subjective sensory complaints and in which the EMG and the motor conduction in the legs is normal.

In the present study, a technique is described to measure the sensory conduction in a nerve not studied previously in the lower extremity, the saphenous nerve. This nerve proved to be easy to locate and it always gave sensory action potentials in normal subjects on adequate stimulation. The conduction velocity values obtained from the saphenous nerve will be compared with those found in other nerves in normal subjects and in patients with polyneuropathy.

MATERIALS AND METHODS

Fifty normal subjects served as controls for the saphenous studies. The majority of these were healthy volunteers, while others suffered from traumatic nerve injuries of the upper extremities only, but showed normal sensory and motor findings in the lower extremities. These controls were divided into two groups according to age.

Thirty-one subjects (23 males, eight females) were between 17 to 38 years (mean age 26) and 19 (15 males,

four females) were 41 to 63 years (mean age 51). In control subjects, 53 saphenous nerves were studied and, in addition, eight subjects underwent measurement of the distal sensory conduction in the posterior tibial nerve. Studies of the distal sensory conduction of the median nerve were also made.

Studies of the sensory conduction in the saphenous nerve were carried out in 65 patients, 36 of whom (31 males, five females) showed clinical signs of polyneuropathy and/or associated slow motor or sensory conduction in some other nerves. The mean age of these cases was 51, ranging from 20 to 76 years. Twenty-nine of the patients (15 males, 14 females) did not show any clinical signs and had no subjective symptoms of polyneuropathy. They suffered from diabetes mellitus, chronic alcoholism, renal insufficiency, or other diseases which may affect peripheral nerves. These 29 cases have for the sake of brevity been called the 'subclinical' group. The mean age of these cases was 36 (19 to 64) years.

Sensory action potentials were recorded both from the posterior tibial and the median nerves. The digital nerves of the first toe and the first finger were stimulated and the action potentials were recorded at the ankle and the wrist respectively by the method described by Buchthal and Rosenfalck (1966).

The saphenous nerve is a terminal sensory branch of the femoral nerve and it innervates the medial surface of the leg from the knee to the foot (Fig. 1). Above the knee, it passes deeply within the subsartorial canal in the thigh and arrives at the level of the inguinal ligament where it joins other motor and sensory branches of the femoral nerve. In the canal as well as at the ligament, it lies close to the motor branches to the vastus medialis muscle. Just under the inguinal ligament it is situated laterally to the point of the maximal pulsation of the femoral artery. It is easy to reach it by a needle electrode at this site.

The following standard procedure was used for the studies of sensory conduction in the saphenous nerve. Stimulation of the sensory nerves was performed with surface electrodes of the same type as those used for stimulating the distal nerves (DISA 13K65). The two electrodes were mounted in parallel, perpendicular to the long axis of the leg just below the lower edge of the patella on the medial surface of the leg. They were placed at a distance of 2 to 3 cm and held in place firmly by surgical tape. Before application of the electrodes the skin was cleaned with ether and gently rubbed with sandpaper.

Electrical stimulation at this site has the advantage of not activating muscle tissue around the electrodes and hence artefacts from muscles are avoided. The proximal

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FIG. 1. Diagram of the saphenous nerve and the position of the electrodes for stimulation and recording. The dotted line shows the course of the saphenous nerve and the solid line indicates the motor fibres of the femoral nerve to the vastus medialis muscle. ST₁ and ST₂: stimulation electrodes for the saphenous nerve. REC: site of the recording electrodes at the inguinal ligament.

stimulating electrode was connected to the cathode of the stimulator.

A concentric needle electrode (DISA 13K03) was placed in the vastus medialis muscle.

The electrodes used for recording sensory action potential were stainless steel needles, Teflon coated except at the tip. The stigmatic electrode had a bare tip of 3 mm and the indifferent a bare tip of 5 mm. In order to reduce the impedance of the electrodes, an alternating current was passed through each electrode for about 30 to 40 seconds, with the electrode placed in hot saline (90°). This procedure produced electrodes with an impedance of 1 to 2 K Ω at 10 to 5,000 c.p.s. measured with a peak to peak voltage of 50 μ V.

The recording electrodes were then connected to the output of the stimulator (DISA Ministim 14 E 30). The stigmatic electrode was inserted at the inguinal ligament about 0.5 to 1.5 cm lateral to the maximum pulsation of the femoral artery, while the indifferent was inserted 1.5 to 3.0 cm more laterally. A long circular ground electrode was placed between the electrodes at the inguinal ligament and in the vastus medialis muscle. With a stimulus duration of 0.2 msec the position of the electrode was then adjusted to a position which gave the lowest threshold for the motor response in the vastus medialis muscle. The mean threshold for obtaining the muscle action potential was found to be 0.6 mA. In a few patients the threshold was about 1.0 mA or slightly higher. In all cases the motor threshold was also determined after recording the sensory action potential. The mean threshold was then found to be 0.7 mA. If the threshold at the end of the study was higher than 1.0 mA the results were

discarded. At the end of the study the motor fibres were stimulated supramaximally—that is, with a stimulus intensity of five to 10 times the motor threshold—and the response in vastus medialis muscle was recorded.

When the recording electrode at the inguinal ligament had been placed as close to the saphenous nerve as possible, the electrodes were connected to the input transformer (ratio 1:30, 10 to 500 c.p.s.) of the electromyograph (DISA 14A30). The differential amplifier of the electromyograph has an input impedance of 200 M Ω shunted with 15 pF, a lower frequency limit (3 dB down) at 2 or 20 c.p.s. (through high pass filter) and an upper frequency limit (3 dB down at 10,000 or 2,000 c.p.s. through a low pass filter) with a slope of 1 dB/octave. The noise level of the amplifier with short circuited input was less than 1.5 μ V RMS, 7 μ V peak to peak.

The saphenous nerve was stimulated on the medial aspect of the knee and in some instances just above the medial malleolus with rectangular pulses 0.2 msec in duration and with an intensity of 40 to 60 mA (DISA Ministim 14 E 10). The stimulus current was monitored through a 10 Ω resistance on one of the channels of the electromyograph.

The sweep speed used for recording the sensory action potential on the film was 0.5 msec/mm or, in some patients with polyneuropathy or in those stimulated at the medial malleolus, 1.0 msec/mm. Twenty superimposed sweeps, as well as single sweeps, were photographed.

The sensory conduction time was measured from the beginning of the stimulus artefact to the peak of the first positive deflection. The distance between the inguinal ligament and the knee was then divided by the conduction time and the conduction velocity was expressed in m/sec. In 10 normal subjects conduction time was obtained by stimulating both at the knee and the medial malleolus. The amplitude of the sensory potential was measured from peak to peak. The motor nerve conduction time to the vastus medialis muscle was measured from the beginning of the stimulus artefact to the onset of the evoked muscle response, the value peak to peak of the first high positive-negative deflection was considered as its amplitude. In every study the deep temperature at the inguinal ligament was measured by an electrothermometer (Ellab-Copenhagen) and found to be 36° to 37°C in both the normal subjects and the patients.

RESULTS

NORMAL SUBJECTS In Table I the results from the studies of sensory conduction in the saphenous nerve and the motor conduction in the femoral nerve are summarized. Figure 2 shows examples of sensory action potentials in the saphenous nerve (left) and evoked motor responses in m. vastus med. at high (middle) and low gain (right) in the low (A) and the high (B) age group.

Figure 3 demonstrates the sensory responses at the inguinal ligament in a 21-year-old normal man to supramaximal stimulation at different levels of the saphenous nerve.

TABLE I
SUMMARY OF RESULTS FROM NORMAL SUBJECTS

	Sensory conduction in saphenous nerve						
	Age (yr)	Mean age	Nerves examined (no.)	Sens. cond. velocity (m/sec)	Sens. cond. time (msec)	Distance (cm)	Amplitude of sens. resp. (μV)
Young normal subjects (knee-ing. lig)	17-38	26	33	59.6 ± 2.3	7.0 ± 0.5	42.2 ± 2.3	4.2 ± 1.8
Old normal subjects (knee-ing. lig)	41-63	51	20	57.1 ± 2.3	7.3 ± 0.5	41.4 ± 3.1	3.6 ± 2.4
Young normal subjects (knee-ing. lig)	17-36	25	10	59.4 ± 2.8	7.1 ± 0.3	42.0 ± 1.2	4.8 ± 2.4
(ankle-knee)				52.3 ± 2.3		26.6 ± 3.8	
(ankle-ing. lig)				56.6 ± 2.0		68.8 ± 3.8	
	Motor conduction in femoral nerve						
	Age (yr)	Mean age	Nerves examined (no.)	Motor conduction time to m. vastus med. (msec)		Distance (cm)	Amplitude of muscle resp. (mV)
Young normal subjects	17-38	26	34	5.05 ± 0.5		28.8 ± 2.3	23.4 ± 11.3
Old normal subjects	41-63	51	20	5.08 ± 0.5		27.5 ± 3.1	21.5 ± 9.9

All values are mean ± S.D.

FIG. 2. Normal sensory action potentials from the saphenous nerve recorded at the inguinal ligament after stimulation of the medial aspect of the knee in two healthy subjects. The middle and right traces show motor responses evoked from the vastus medialis muscle by supramaximal stimulation at the inguinal ligament both at high and low amplifications. All sensory responses are 20 superimposed potentials. The figures for sensory action potentials give the conduction velocity between the knee and the inguinal ligament and the figures for the motor responses show the distances between the inguinal ligament and recording sites in the vastus medialis muscle. A. Y.F., 27-year-old female (6 December 1967). The distance between knee and inguinal ligament is 42 cm. B. S.C., 52-year-old male (11 September 1967). The distance between knee and inguinal ligament is 40.5 cm. (In this figure and in all subsequent figures, a downward deflection of the trace is positive.)

FIG. 3. Normal sensory action potentials from the saphenous nerve recorded at the inguinal ligament (Rec) after stimulation at the knee (ST₁) and above the medial malleolus (ST₂) in a healthy subject. A.N., 21-year-old male (18 January 1968). The distance between ST₁-ST₂ is 25.2 cm and ST₁-Rec 42.1 cm. All sensory responses are 20 superimposed potentials.

The mean sensory conduction velocity in the saphenous nerve between the knee and the inguinal ligament was 59.6 m/sec in young and 57.1 m/sec in old normal subjects. The mean amplitude of the sensory action potentials recorded at the inguinal ligament after stimulation at the knee was 4.2 μ V in the young and 3.6 μ V in the old group. The shape of the sensory action potentials was in most instances triphasic but many of the cases had in addition smaller sharp late deflections. The difference in sensory conduction between the two groups was significant ($P < 0.001$). Below the age of 30, sensory conduction velocity in all normal subjects was above 55 m/sec but some subjects over 50 years had conduction velocities below 55 m/sec, but none was recorded below 52 m/sec. The amplitude of the sensory action potentials and the distances between stimulation and recording sites did not differ significantly in the two different age groups.

In 10 normal subjects (age 10 to 36 years), the sensory conduction velocity in the lower segment medial malleolus-knee of the saphenous nerve was 52.3 m/sec. This is significantly ($P < 0.001$) slower than the conduction velocity in the proximal segment (knee-lig. ing.). The mean sensory conduction along the whole length of the leg was 56.6 m/sec.

In eight normal subjects with a mean age of 45 years (33 to 59 years), sensory conduction was investigated both in the proximal segment of the saphenous nerve and in the posterior tibial nerve (first toe-ankle segment). In seven other normal subjects sensory conduction was determined both in the proximal segment of the saphenous nerve and in the median nerve (stimulation of the thumb recording at the wrist). The results from these two

groups are given in Table II. Figure 4 gives some examples from such comparisons. In the group where sensory conduction in the saphenous nerve was compared with that in the posterior tibial nerve, all eight subjects had detectable saphenous nerve sensory potentials but only six of them showed a detectable sensory response at the ankle on stimulation of the digital nerves of the first toe. Moreover,

FIG. 4. Sensory action potentials recorded from the saphenous nerve at the inguinal ligament (upper traces) and the posterior tibial nerve at the ankle (lower trace) in two healthy subjects (A, B) and from the median nerve at the wrist (middle trace) in a healthy subject (C). All sensory responses are 20 superimposed potentials. Figures on each trace give the distances between stimulation and recording sites. A. M.G., 36-year-old female (7 July 1967). B. S.E.J., 37-year-old female (14 July 1967). C. K.H., 28-year-old female (18 January 1968). Vertical scales indicate 8 mV. Horizontal scales indicate 5 msec.

TABLE II
COMPARISON OF SENSORY CONDUCTIONS IN NORMAL SUBJECTS

(A) Between posterior tibial and saphenous nerve ¹							
	Age (yr)	Mean age	Sensory conduction veloc. first toe-ankle or knee-inguinal ligament (m/sec)	Sensory conduction time first toe-ankle or knee-inguinal ligament (msec)	Distances (cm)	Amplitude of sens. responses at ankle or at ing. lig. (μ V)	No. recordable sens. potentials (no. of nerves)
Posterior tibial nerve	33-59	45	35.7 $\pm$ 3.8	5.8 $\pm$ 0.6	20.5 $\pm$ 1.1	1.33 $\pm$ 0.4	2
Saphenous nerve	33-59	45	57.2 $\pm$ 2.3	7.4 $\pm$ 0.5	42.2 $\pm$ 2.5	4.4 $\pm$ 2.6	0
(B) Between median (distal segment) and saphenous nerves ²							
	Age (yr)	Mean age	Sensory conduction veloc. first finger-wrist or knee-ing. ligament (m/sec)	Sensory conduction time first finger-wrist or knee-ing. ligament (msec)	Distance (cm)	Amplitude of sens. responses at wrist or at ing. ligament (μ V)	No. recordable sens. potentials (no. of nerves)
Median nerve	21-52	35	49.2 $\pm$ 7.4	2.6 $\pm$ 0.5	12.4 $\pm$ 0.3	23.1 $\pm$ 10.9	0
Saphenous nerve	21-52	35	58.7 $\pm$ 3.1	6.8 $\pm$ 0.5	39.2 $\pm$ 2.1	5.6 $\pm$ 3.3	0

All values are mean $\pm$ S.D.
¹Eight normal subjects.
²Seven normal subjects.

the amplitude of the saphenous sensory response was higher than the response in the posterior tibial nerve despite the longer distances involved in the saphenous nerve. Certainly, the mean amplitude was found significantly higher in the saphenous nerve than in the posterior tibial nerve ($P < 0.005$). The sensory conduction velocity was also faster in the saphenous nerve than in the posterior tibial nerve ($P < 0.001$).

To compare the sensory conduction in the saphenous and in the median nerves, seven unselected normal subjects were examined. The distal segment of the median nerve did not show a significantly slower sensory conduction than the proximal segment of the saphenous nerve ($P > 0.05$). However, the amplitudes of the sensory responses in the median nerve were significantly higher than those in the saphenous nerve ($P < 0.001$).

The mean motor conduction time to the vastus medialis muscle was 5.05 msec in the younger group (mean distance 28.8 cm) and 5.08 msec in the older group (mean distance 27.5 cm). Variations were 4.0 to 6.0 msec in young (distances 21.7 to 34.5 cm) and 4.0 to 6.2 msec in old normal subjects (distances 20.6 to 32.6 cm). There was a slightly longer motor conduction time in the old than in the young group ($P < 0.001$), while the distances did not differ significantly. The distance between the inguinal ligament and the recording sites in the muscle affected the motor conduction time, distances greater than 32 cm gave latencies greater than 5.5 msec, while those less than 25 cm had latencies less than 5.0 msec.

PATIENTS In Table III, the patients examined are listed with their clinical diagnoses. Table IV displays the results for mean sensory conduction velocities in the saphenous and the distal part of the median nerve, as well as the results of the motor conduction measurement in the femoral nerve.

Thirty-six cases with clinically manifest polyneuropathy were investigated. In 15, there were no recordable potentials at the inguinal ligament, while

TABLE III
NUMBER OF PATIENTS IN DIFFERENT DIAGNOSTIC GROUPS

	Poly-neuropathy	No clinical poly-neuropathy	Total
Diabetes mellitus	10	12	22
Chronic alcoholism	6	11	17
Patients with diseases associated with or without polyneuropathy:			
Renal insufficiency	4	3	7
Polyarteritis nodosa	2	1	3
Porphyria	1	—	1
Guillain Barré	1	—	1
Carcinoma of lung	1	—	1
B12 deficiency	—	1	1
Lead intoxication	—	1	1
Patients with unknown aetiology	11	—	11
	36	29	65

the remaining 21 showed measurable potentials. The mean sensory conduction velocity was 49.7 m/sec, which is slower than in the normal subjects ($P < 0.001$). Seven cases, however, had velocities faster than 52 m/sec—that is, within the normal range. The amplitude at the inguinal ligament was also significantly reduced with a mean of $1.3 \mu V$ ($P < 0.001$).

The femoral motor conduction time was prolonged in a number of the cases with the mean values of 7.2 msec ranging 4.0 to 19.0 msec ($P < 0.001$). Prolonged femoral motor conduction time was usually associated with slow sensory conduction velocity or absence of sensory response, whereas a normal motor conduction time was found both in cases showing slow and normal sensory conduction.

Thirty-four of these 36 cases were also investigated for sensory conduction in the distal part of the median nerve. In four cases no median sensory action potentials were recorded. The remainder had a mean of median nerve sensory conduction velocity of 38.3 m/sec and a mean amplitude of $6.1 \mu V$. Both values are significantly smaller than in normal subjects ($P < 0.001$) compared with the normal values at 40 to 61 years from the study of Buchthal

TABLE IV
MEAN VALUES DETERMINED FROM THE INVESTIGATION OF 65 PATIENTS

	Saphenous nerve				Femoral nerve					Median nerve			
	Mean age	Nerves exam. (no.)	Sens. cond. vel. knee-ing. lig. (m/sec)	Ampl. of sens. resp. (μV)	No resp. (no. of nerves)	Nerves exam. (no.)	Mot. cond. time to vast. med. (msec)	Distance (cm)	Ampl. of muscle resp. (mV)	Nerves exam. (no.)	Sens. cond. vel. 1. fing.-wrist (m/sec)	Ampl. of sens. resp. (μV)	No resp. (no. of nerves)
Clinical poly-neuropathy	51	36	49.7 $\pm$ 4.7	1.29 $\pm$ 0.5	15	36	7.20 $\pm$ 2.6	28.8 $\pm$ 2.4	11.3 $\pm$ 9.3	34	38.3 $\pm$ 7.5	6.1 $\pm$ 4.4	4
Subclinical cases	36	29	54.5 $\pm$ 3.6	1.9 $\pm$ 0.9	0	29	5.47 $\pm$ 0.8	28.5 $\pm$ 3.7	18.0 $\pm$ 10.5	24	43.8 $\pm$ 7.2	13.7 $\pm$ 6.8	0

All values are mean $\pm$ S.D.

and Rosenfalck (1966). However, in 12 of 34 cases, sensory conduction velocity was still within the normal limits, although an amplitude reduction was observed in some of them.

Twenty-nine patients who all suffered from diseases which sometimes affect the peripheral nerves, but in whom careful clinical examination did not reveal signs of polyneuropathy, were investigated (sub-clinical group). All patients showed sensory potentials at the inguinal ligament. The mean conduction velocity was 54.5 m/sec. These values are significantly lower than the values obtained for corresponding normal age groups ($P < 0.001$). The mean amplitude for the group was 1.9 μ V, a significant reduction from normal values ($P < 0.001$). The mean motor conduction latency in the femoral nerve was 5.47 msec, which is moderately prolonged ($P < 0.01$).

Twenty-four of these 29 cases were investigated for sensory conduction in the distal part of the median nerve. A mean sensory conduction of 43.8 m/sec was found, which is slower ($P < 0.005$) than in young normals. The value is, however, not significantly different from middle age normals ($P > 0.05$) (Buchthal and Rosenfalck, 1966). The mean amplitude was 13.7 μ V, which was significantly decreased ($P < 0.001$) in comparison with young normal subjects.

The results from all patients with and without clinically manifest polyneuropathy are shown in Fig. 5, together with normal values. It was not possible to demonstrate clear-cut differences between the various diagnostic groups as to differential involvement of the femoral and the saphenous nerves. Nevertheless, diabetic cases seemed to lack sensory responses more frequently and to have prolonged motor latencies more often, although, in one case with porphyria and two others with renal insufficiency, femoral motor latency was markedly prolonged and there were no sensory responses in the saphenous nerve.

A comparison of the sensory conduction velocities in the saphenous and in the median nerves showed that the sensory conduction velocity was reduced in the saphenous nerve in 85% and in the median nerve in 65% of the cases with manifest polyneuropathy. In the subclinical group, 31% of the patients had a sensory conduction velocity in the saphenous nerve below the lower normal limit, while 29% had a slow sensory conduction velocity in the median nerve (see Figs. 6, 7, 8 for individual recordings of the patients).

DISCUSSION

NORMALS In the study of Gilliatt, Goodman, and

Willison (1961), describing nerve action potentials from the lateral popliteal nerve in man, the authors were not able to record sensory action potentials at the ankle with stimulation of the digital nerves in the toes. Instead, they investigated mixed nerve action potentials recorded at the head of the fibula after stimulation of the nerve at the ankle. Similarly, Mayer (1963), and Mayer and Mawdsley (1965), were rarely able to record sensory action potentials at the ankle on stimulation at the foot for either posterior tibial or common peroneal nerves. Similar difficulties were reported during attempts to record sensory action potentials regularly from the sural nerve in normal human subjects (Deaton and Downie, 1967).

By introducing new techniques to record very small action potentials using either an averaging computer (Dawson, 1954), a barrier grid storage tube (Jensen, 1965; Gilliatt, Melville, Velate, and Willison, 1965), or a step-up input transformer (Buchthal and Rosenfalck, 1965, 1966), it is possible to measure the sensory conduction velocities in the leg nerves. Thus, conduction velocities have been obtained in the posterior tibial nerve (Mavor and Atcheson, 1966) and in the sciatic nerve and its distal branches (Buchthal and Rosenfalck, 1966). In these two studies of normal subjects, the ages were 15 to 35 and 18 to 25 years respectively. For the posterior tibial nerve, the mean amplitude of the sensory responses recorded at the ankle was 3.8 and 3.0 μ V in these studies. Older normal individuals and patients with neuropathy were not suitable subjects for investigation, since their sensory potentials were too small.

The method for recording saphenous nerve conduction described in this article offers the following advantages

1. It permits sensory action potentials to be recorded regularly at the inguinal ligament after stimulation of the medial side of the knee in all normal subjects studied up to the age of at least 63 years. The responses could be recorded in some patients over 65 as well (two of three cases).
2. A comparison in eight normal subjects with the mean age of 45 years ranging from 33 to 59 showed that the saphenous nerve is an alternative for measurement of sensory function in the lower limbs. In all cases, the sensory action potentials in the saphenous nerve could be evoked at greater amplitude than in the posterior tibial nerve.
3. The method does not require an averaging computer.

Standardization of the position of the needle electrode at the inguinal ligament was made by determining the threshold for stimulation of the motor fibres of the femoral nerve. This method has

FIG. 5. Individual values for sensory conduction velocity in the saphenous nerve and for motor conduction time in the femoral nerve plotted according to aetiological groups. Filled circles denote patients with clinical polyneuropathy (PN) and open circles patients without clinical polyneuropathy (Subc). Filled triangles are normal subjects. The values at the top of each column are mean $\pm$ S.E.M. and S.D.

the disadvantage that the position of the saphenous nerve in relation to the femoral nerve might vary between subjects and thus the distance between the recording electrode and the saphenous nerve will vary in accordance. This disadvantage could be overcome by placing the recording electrode so that a minimal stimulus through it will give a subjective sensory response, but this method was not used as it requires the co-operation of the patient.

Saphenous nerve conduction in man was first

investigated by Heinbecker, Bishop, and O'Leary (1933). They exposed the nerve in a diabetic patient with gangrene of the foot, and stimulated it directly without an anaesthetic, as well as after excision of the nerve about half an hour later. In this way they found a fast component conducting at 100 m/sec, a slower one conducting at 25 m/sec, and, with stimulus strength sufficient to stimulate all fibres of the nerves, an additional component conducting at 1.5 m/sec. Such exposure techniques are clearly not applicable to routine clinical examinations.

FIG. 6. Patients with diabetes mellitus. Sensory action potentials from the saphenous and median nerves recorded at the inguinal ligament and at the wrist after stimulation at the knee and first finger respectively (first and third columns) and the motor responses recorded from the vastus medialis muscle with stimulation at the inguinal ligament supramaximally (second column). All sensory responses are 20 superimposed potentials. Figures on each trace for sensory responses give the conduction velocity in m/sec and figures on each trace for motor responses show the distances between stimulation and recording sites in the muscle. A. E.W., 23-year-old female (467/67, 1 September 1967). Duration of diabetes is six weeks. No clinical neuropathy. Normal values for three nerves. B. M.H., 27-year-old female (3/68, 2 January 1968). Duration of diabetes is nine years, no clinical neuropathy. Slow sensory conduction in the saphenous nerve, normal values in the femoral and median nerves, while the amplitude of the sensory responses at the wrist is reduced. C. F.W., 29-year-old male (489/67, 11 September 1967). Duration of diabetes is 10 years. Clinically mild neuropathy. Slow sensory conduction in both nerves with prolonged femoral nerve motor conduction time (7.0 msec). D. W.S., 59-year-old male (408/67, 7 August 1967). Duration of diabetes is about one year. Clinically sensory-motor symmetrical polyneuropathy with subacute onset. No certain sensory response in the saphenous nerve and slow sensory conduction in the median nerve. Femoral nerve conduction time is also prolonged (8.0 msec). Vertical scales indicate 6 mV, horizontal scale 5 msec.

FIG. 7. Patients with chronic alcoholism. Same arrangement of columns as in Fig. 6. A. L.H., 27-year-old male (710/67, 23 November 1967). Heavy drinking every day for four years. One month earlier mental symptoms appeared. No clinical neuropathy. Values for median and femoral nerves are within the normal limits, but sensory conduction in the saphenous nerve is below the normal range of the younger normal subjects. B. J.K., 29-year-old male (692/67, 20 November 1967). Heavy drinker every day for seven years. Hepatic cirrhosis is present. Clinically no neuropathy. The value for sensory conduction in the saphenous nerve is below the normal range for younger normal subjects while the values for the median and the femoral nerves are normal. C. G.N., 62-year-old male (796/67, 27 December 1967). Many years of alcoholism. Clinically mild polyneuropathy. The values for sensory conduction in both nerves are slow, but femoral conduction time is 6.5 msec. Vertical scales indicate 6 mV. Horizontal scales indicate 5 msec.

FIG. 8. Patients with renal insufficiency and polyangeitis nodosa. Same arrangement of columns as in Fig. 6. A. A.G.S., 51-year-old female (20/68, 20 November 1968). Bilateral renal cyst for five years with exacerbation of chronic pyelonephritis and renal insufficiency. Clinically no neuropathy. The values for all three nerves are within the normal limits, but the sensory conduction in the saphenous nerve is close to the lower range of normal older subjects. B. L.N., 31-year old male (695/67, 20 November 1967). Three years chronic renal insufficiency with nephrolithiasis. Clinically mild polyneuropathy. The sensory conduction in the saphenous nerve is slow, but still within the normal limits in the median nerve, although the amplitude of the sensory response at the wrist reduced. Femoral conduction time is also prolonged (7.0 msec). C. M.J., 22-year-old male (706/67, 22 November 1967). Seven years progressive renal insufficiency with renal cyst. For one year under dialysis. Clinically severe sensory and motor polyneuropathy. No recordable sensory potentials in the saphenous nerve and slow sensory conduction in the median nerve. Femoral conduction time is extremely prolonged (14.0 msec): note the slow sweep speed. D. B.T., 45-year-old male (31/68, 17 January 1968). Polyangeitis nodosa diagnosed 2.5 years earlier. Clinically mild polyneuropathy. Slow sensory conduction velocities in the saphenous and the median nerve, while normal femoral conduction time. Vertical scales indicate 6 mV, horizontal scales 5 msec.

The mean sensory conduction velocity of 59.6 m/sec in the proximal segment of the saphenous nerve in young normal subjects is similar to that in the proximal segment of the sciatic nerve between fossa poplitea-buttock with the mean of 62.4 m/sec as determined by Buchthal and Rosenfalck (1966); and considerably slower than that in the proximal segments of the median nerve (elbow to axilla) in

both young and older subjects reported in the literature (Buchthal and Rosenfalck, 1966; Kemble and Peiris, 1967). With increasing age, the sensory conduction velocity was found to be slower in the saphenous nerve, a finding that agrees with other studies on other sensory nerves (Downie and Newell, 1961; Mayer, 1963; Buchthal and Rosenfalck, 1966). The distal segment of the saphenous nerve had a lower conduction velocity than that of the proximal segment determined in 10 young normal subjects. This is also similar to observations in other mixed and sensory nerve conduction studies (Magladery and McDougal, 1950; Mayer, 1963; Buchthal and Rosenfalck, 1966; Kemble and Peiris, 1967).

The findings for the femoral conduction time in normal subjects is slightly shorter than in the studies of Gassel (1963) and of Chopra and Hurwitz (1968). The slightly different values obtained in the present study despite the comparable distances were probably due to use of the vastus medialis muscle in contrast to the other two studies mentioned above, where the evoked muscle action potentials were recorded from the rectus femoris muscle.

PATIENTS In the patients with and without signs of clinical polyneuropathy the sensory conduction in the saphenous nerve differed from the normal values. These changes in sensory conduction occurred both in presence and absence of corresponding disturbances in the median sensory and in the femoral motor nerves.

The fact that 85% of the cases with clinical polyneuropathy have either absence of sensory response at the inguinal ligament or less than 52 m/sec conduction velocities in the saphenous nerve shows that the nerve is frequently involved in polyneuropathy; while the femoral conduction time of 7.0 msec or more was found in about 39% of all cases with neuropathy. Therefore the saphenous nerve conduction seems to be affected more than twice as often as that of the femoral nerve. These findings are in agreement with the pathological findings that changes in sensory fibres occur before those in motor fibres in different kinds of neuropathies (Gilliat and Thomas, 1960; Gilliat, 1961; Gilliat *et al.*, 1961; Gilliat and Willison, 1962; Downie, 1964; and others). Although such parameters as amplitude and duration of the sensory potentials recorded at the wrist in the median nerve deviate significantly from normal values and limits, sensory conduction velocity in the distal part of the median nerve below the borderline of the normal or no recordable sensory potentials at wrist was found in 65% of the cases with polyneuropathy in contrast to 85% of the cases in the saphenous nerve. This greater incidence of deviations from normal limits

in sensory conduction velocity in the saphenous nerve than in the median nerve would parallel the clinical findings that in many cases leg nerves were involved more than arm nerves.

In 29 subclinical cases associated with different diseases, there was no sign that could be interpreted as evidence of polyneuropathy, yet the saphenous nerve conduction velocity was significantly lowered in 31% of the cases, being below the lower limit of the normal range. While two cases had a femoral motor nerve latency of 7.0 msec, the mean of the femoral conduction time was significantly prolonged. The sensory conduction in the distal part of the median nerve was almost equally involved in 29% of cases but was statistically closer to normal values than that of the saphenous nerve. Slow sensory conduction found in such subclinical cases in different nerves has been reported previously (Downie and Newell, 1961; Mayer, 1963; Preswick and Jeremy, 1964; Mawdsley and Mayer, 1965; Jebsen, Tenckhoff, and Honet, 1967; and others).

The method for measurement of the sensory conduction in the saphenous nerve appears to be of value to reveal subclinical changes in sensory nerve fibres in the leg. Furthermore, as is stated by Chopra and Hurwitz (1968), both femoral and saphenous nerves are less liable to compression and trauma anatomically than the median, ulnar, and lateral popliteal nerves. Therefore in such situations, measurement of the saphenous nerve conduction provides a more useful clinical aid than studies of the other nerves mentioned, especially in subclinical polyneuropathies.

The material presented in this study is not sufficient for valid comparisons between disease of different aetiology, such as diabetes, chronic alcoholism, uraemia, but in diabetes the saphenous and femoral nerves seemed to be more frequently involved. These findings are in agreement with the clinical observations in diabetes mellitus of Hirson, Feinmann, and Wade (1953); Goodman (1954) and Calverley and Mulder (1960), and of the electrophysiological studies of Chopra and Hurwitz (1968); Garland and Taverner (1953) ascribed diabetic amyotrophy to a condition affecting the spinal cord, but Gilliat and Willison (1962), in an electrophysiological investigation, concluded that it was a motor neuropathy. Chopra and Hurwitz (1968) also came to this conclusion by their conduction studies in the femoral nerve in diabetics and chronic occlusive vascular disease. Unfortunately, there was no case which had the features resembling diabetic amyotrophy in the present material, but, since the sensory conduction in the saphenous nerve as a terminal sensory branch of the femoral nerve was affected more than twice as often as that of the femoral nerve in neuropathies

including diabetes, it would be interesting from conduction studies to learn whether the cases with this syndrome display mainly a motor neuropathy or involve both sensory and motor fibres.

SUMMARY

1. A method is described of recording sensory potentials in the saphenous nerve in man.
2. The suitability of this nerve for clinical sensory conduction velocity measurement in the leg is discussed.
3. It is shown that the saphenous nerve may display early changes in sensory conduction in patients without clinical polyneuropathies as well as frequent involvement of the nerve in patients with clinical polyneuropathies.
4. More severe affection of sensory conduction in the saphenous nerve in combination with or without prolonged femoral nerve conduction may occur in diabetes more frequently than in other diseases associated with neuropathy.

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