Table 1—Classification of nerve conduction study results

Grade 0	No detectable abnormality
Grade 1	Very mild
Grade 2	Mild (sensory conduction velocity < 40 m/sec, motor terminal latency < 4.5 msec)
Grade 3	Moderately severe (motor terminal latency > 4.5 msec < 6.5 msec, preserved sensory potential)
Grade 4	Severe (motor terminal latency > 4.5 msec, absent sensory potential)
Grade 5	Very severe (motor terminal latency > 4.5 msec < 6.5 msec)
Grade 6	Extremely severe (compound motor potential from abductor pollicis brevis < 0.2 mV)

the sensory nerve action potential amplitude occurs earlier in carpal tunnel syndrome than a decrease in the compound muscle action potential (Graham et al., 1983; Stevens, 1987). It is also assumed that techniques that assess sensory nerve conduction velocity over a short distance (e.g. palm-wrist) are superior to those that use a longer distance (AAEM Quality Assurance Committee, 1993). Our categories are based on the published data of Bland (2000), whose neurophysiological severity scale correlates well with clinical severity.

The operation

All patients underwent carpal tunnel decompression surgery as day cases. The operations were performed under local anaesthetic with a high arm tourniquet. 29 patients had the operation on the left, 33 on the right.

Statistical analysis

χ^2 tests were performed to investigate the relationship between pre-operative symptomatology and the severity of electrophysiological impairment. Correlation coefficients were calculated to investigate the relationship between the severity of electrophysiological impairment and both pre-operative symptom duration and post-operative time to loss of symptoms after surgery.

RESULTS

Sixty two patients attended for review at the special assessment clinic. All had undergone preoperative nerve conduction studies, and all underwent carpal tunnel decompression surgery at the Royal Victoria Infirmary between June 1998 and June 1999. Thirty five were women, 27 were men. Thirty-three were right handed. Six were diabetics and four were dysthyroid.

The median duration of symptoms was 2 years (interquartile range, 1–4 years). Figure 1 illustrates the relative frequency of pre-operative symptoms amongst the 62 patients. The nerve conduction results, classified according to grade of severity, are illustrated in Table 2. Most patients had a result within the middle range of values.

There was only a poor correlation between symptom duration and the severity of electrophysiological abnormality (correlation coefficient = +0.24: Figure 2). There was no relationship between the presence of pain ($P = 0.498$: Figure 3) or the presence of reduced digital

Table 2—Nerve conduction study results (graded according to severity, scale 0 to 6) and number of patients in each grade who obtained complete symptom resolution after surgery

Electrophysiological grade	Number of patients at each grade	Number of patients with complete loss of symptoms after surgery
Grade 0	4	2
Grade 1	18	8
Grade 2	8	5
Grade 3	15	8
Grade 4	8	5
Grade 5	5	4
Grade 6	4	0

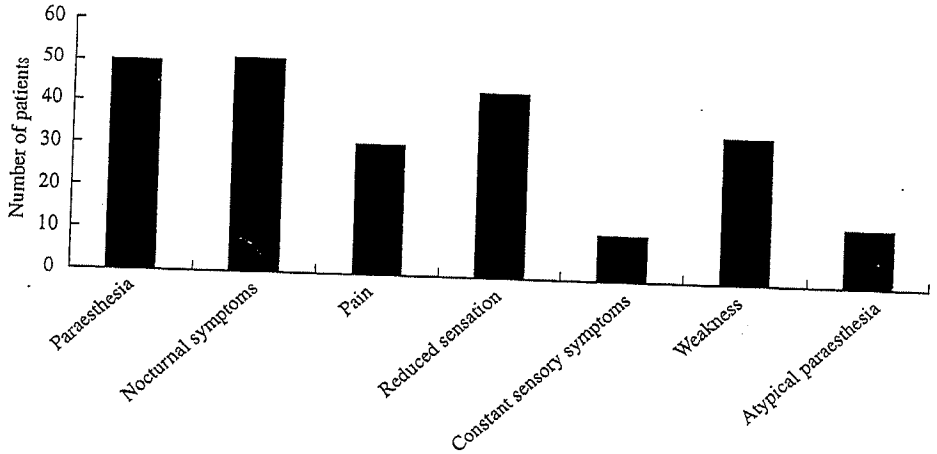


Fig 1 Frequency of pre-operative symptom duration in 62 patients.

VII. Variations and Pitfalls
  A. Large shock artifact is sometimes hard to avoid because of the short distance and because the ground is not located between G1 and S1.
  B. If too much power is used it is possible to stimulate and record from other muscles, such as the masseter, which will yield an erroneous response, or a spuriously high amplitude.
VIII. Normal Values
  A. The distal latency and amplitude are based on a side-to-side comparison.
  B. Be sure that electrodes are symmetrically placed to insure accurate comparisons.

UPPER EXTREMITY STUDIES

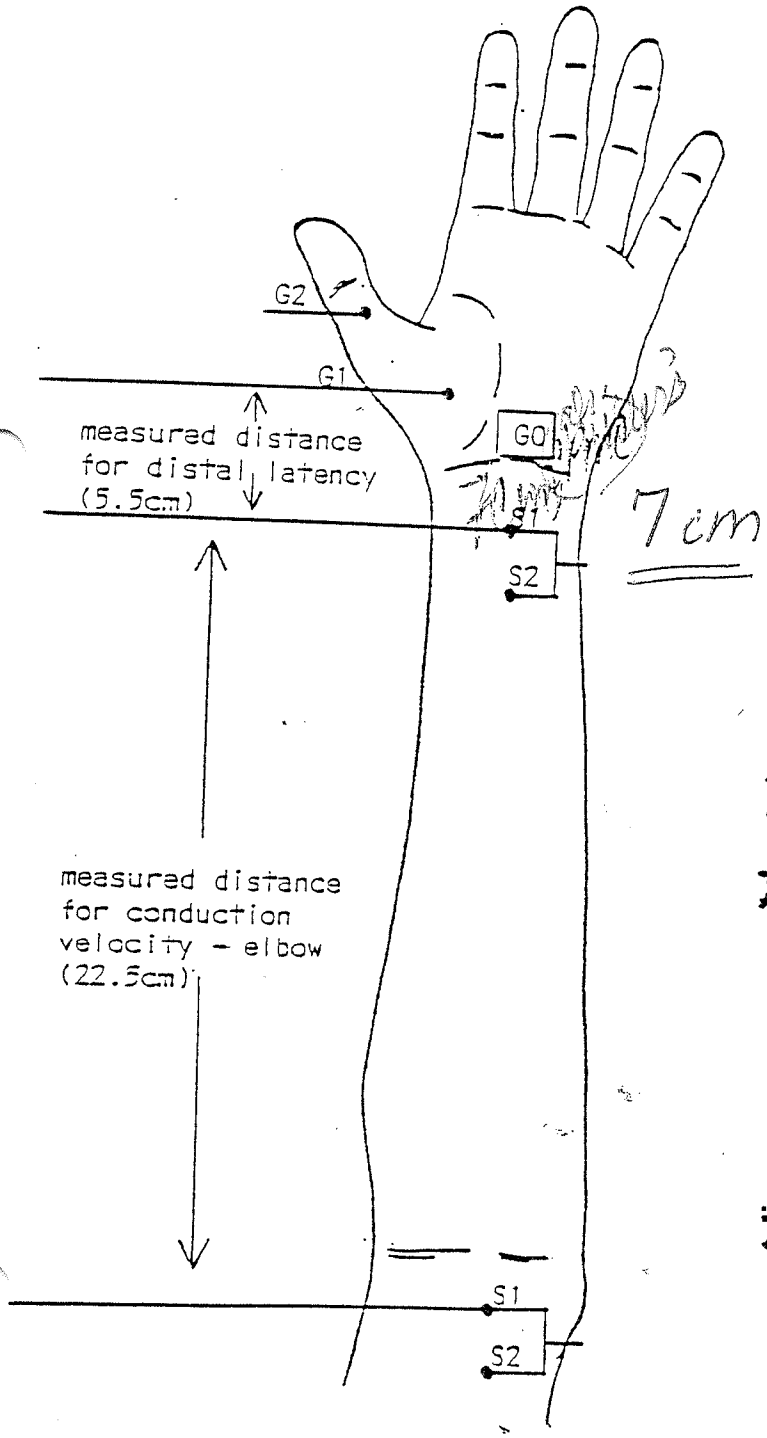
Median (motor)/abductor pollicis brevis (10, 48, 50)

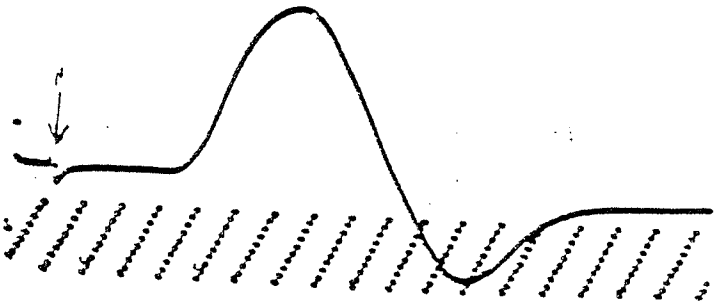
I. Position of Patient
  A. Patient is supine with upper extremity supinated and extended at side.
  B. Upper extremity is supported by the bed at all times.
II. Equipment
  A. 2 disc electrodes (G1 active, G2 reference)
  B. 1 ground (G0)
  C. 1 bipolar stimulator (S1 cathode, S2 anode)
III. Machine Settings
  A. Sweep speed (ms/div)—2 to 5
  B. Gain (mv)—1 to 10
  C. Filters—1.6(Hz), 8(KHz)
IV. Electrode Placement
  A. G0 (ground)—palm of hand between G1 and distal S1
  B. G1 (active)—over the belly of the muscle abductor pollicis brevis (thenar group), approximately one third the distance (proximal to distal) and medial to the first metacarpal bone in line with the anterior aspect of thumb.
  C. G2 (reference)—midportion of the proximal phalanx of the thumb.
V. Stimulation Sites and Measurements
  A. Wrist (distal):
    1. Stimulate—S1, between the flexor carpi radialis tendon and the palmaris tongus tendon, 3 to 5 cm proximal to the distal wrist crease.
    2. Measure—distance from S1 to G1 in a straight line. On adults use a distance between 4.5 and 6.5 cm.

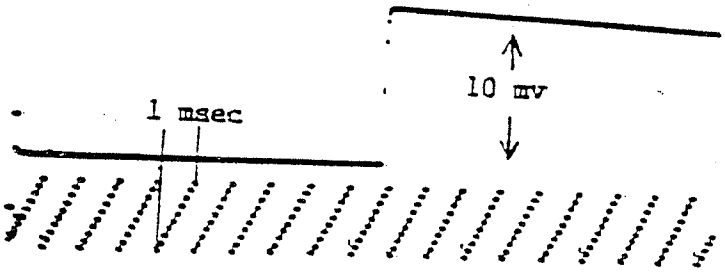
MEDIAN (motor) / abductor pollicis brevis

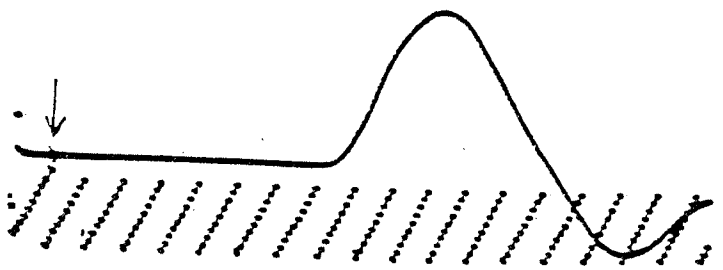
age = 38

Stimulation Site	Amp. mv	Latency msec	Dist. cm	C.V. M/sec
elbow	10.0	7.2	22.5	58
wrist	11.0	3.3	5.5	
		3.9		









B. Elbow:
   1. Stimulate—S1, over the pulse of the brachial artery (in the anticubital fossa), 3 to 5 cm proximal to the elbow crease.
   2. Measure—distance from elbow-S1 to wrist-S1 in a straight line along the anterior portion of the forearm.

VI. Calculations
   A. Distal Latency—Calculate from shock artifact to the takeoff of the negative deflection of the distal response.
   B. Amplitude—Calculate from baseline to the peak of the negative deflection.
   C. Conduction Velocity—Using latencies measured to the takeoff, subtract the distal from the proximal latency, divide the difference into the distance between proximal-S1 and distal-S1, and multiply by 10.

VII. Variations and Pitfalls
   A. Amplitude and configuration of response may vary depending on the placement of G1.
   B. If the elbow amplitude is higher than the wrist amplitude:
      1. Check movement elicited to see if thenar-ulnar muscle (FPB) is also being stimulated. This is a problem especially in thin patients when too much power is used.
      2. Check for median to ulnar crossover (see Chapter 5).
   C. If configuration or amplitude changes between proximal and distal stimulation sites:
      1. Check for electrode movement.
      2. Check if thenar-ulnar muscle is being stimulated.
      3. Check if stimulation is maximal at both points.
   D. Amplitude and configuration changes may be seen with axilla and Erb's point stimulation due to the volume conduction of ulnar innervated thenar muscles such as the flexor pollicis brevis.

VIII. Normal Values* MEDIAN

AGE	AMPLITUDE mv	DISTAL LATENCY msec	CONDUCTION VELOCITY m/sec (>50 m/s)
0-9	5-14 (9)	2.0-3.0 (2.4)	48-66 (58)
10-19	6-17 (11)	2.2-3.4 (3.0)	54-66 (60)
20-29	6-20 (12)	2.3-3.9 (3.0)	53-69 (60)
30-39	6-25 (12)	2.2-3.8 (3.1)	52-67 (60)
40-49	6-18 (11)	2.3-3.9 (3.1)	51-68 (59)
50-59	6-19 (11)	2.3-4.0 (3.2)	51-64 (58)
60-69	5-20 (10)	2.6-4.0 (3.3)	50-65 (56)
70-	5-16 (8)	2.6-4.0 (3.3)	50-61 (54)

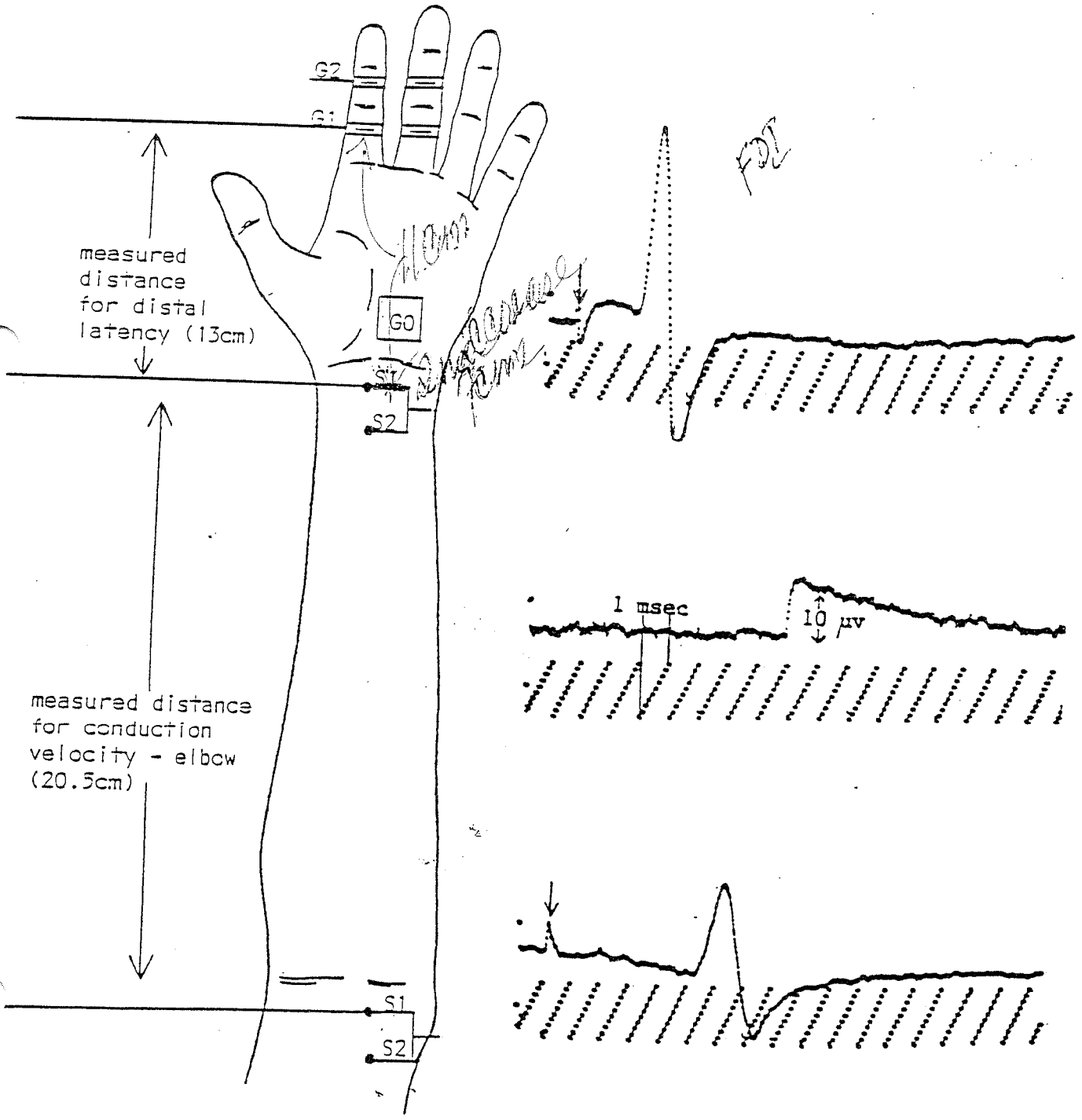
*Normals obtained from the Cleveland Clinic Foundation EMG Laboratory, divided into decades, are based on a sampling of at least ninety patient-normals for all age groups except age groups of 10-19 year and over 70 years, which are based on a sampling of at least forty patient-normals. All normals are based on a supramaximal distal amplitude (except if other site is specified) and on the standard distance or distance range specified for each study.

MEDIAN (sensory-antidromic) / index and middle fingers

age = 46

Stimulation Site	Amp. μv	Latency msec	Dist. cm	C.V. M/sec
elbow wrist	16 30	(5.3) (2.2)2.9 (3.1)	20.5 13.0	66

( ) = take off



Median (sensory-antidromic)/ index and middle fingers (thumb) (10, 48, 50)

I. Position of Patient
   A. Patient is supine with upper extremity supinated and extended at side.
   B. Upper extremity is supported by the bed at all times.

II. Equipment
   A. 2 sensory clip electrodes (G1 active, G2 reference)
   B. 1 ground (G0)
   C. 1 bipolar stimulator (S1 cathode, S2 anode)

III. Machine Settings
   A. Sweep speed (ms/div)—1 to 2
   B. Gain (μv)—5 to 20
   C. Filters—32 (Hz), 1.6 (KHz)

IV. Electrode Placement
   A. G0 (ground)—palm of hand between G1 and distal S1.
   B. G1 (active)—midportion of the proximal phalanx of both index and middle fingers.
   C. G2 (reference)—midportion of the middle phalanx on the same finger as G1, 2.5 to 3 cm from G1.

V. Stimulation Sites and Measurements
   A. Wrist (distal):
      1. Stimulate—S1, between the flexor carpi radialis tendon and the palmaris longus tendon, 3 to 5 cm proximal to the distal wrist crease.
      2. Measure—distance from S1 to G1 in a straight line. On adults use a distance of 13 cm if possible.
   B. Elbow:
      1. Stimulate—S1, over the pulse of the brachial artery (in the antiicubital fossa), 3 to 5 cm proximal to the elbow crease.
      2. Measure—distance from elbow-S1 to wrist-S1 in a straight line along the anterior portion of the forearm.

VI. Calculations
   A. Distal Latency—Calculate from the shock artifact to the peak of the negative deflection of the distal response.
   B. Amplitude—Calculate from baseline to the peak of the negative deflection.
   C. Conduction Velocity—Using latencies measured to the takeoff, subtract the distal from the proximal latency, divide the difference into the distance between proximal-S1 and distal-S1, and multiply by 10.

VII. Variations and Pitfalls
   A. An antidromic median sensory may also be recorded from the thumb by placing G1 on the mid portion of the proximal

phalanx. G2 on the mid portion of the distal phalanx, and stimulating at the wrist, 13 cm from G1.

B. Amplitude normal for thumb recordings are slightly lower than amplitude normals found with index or middle finger recording. Distal latency normals are the same as the index and middle fingers provided the same distance is used.

C. If distance other than 13 cm is used, add or subtract 0.2 msec for each cm difference.

D. Cold may cause a prolonged distal latency with a normal amplitude.

VIII. Normal Values* MEDIAN SENSORY ANTIDR

AGE	AMPLITUDE mv	DISTAL LATENCY msec	CONDUCTION VELOCITY m/sec
0-9	20-70 (40)	2.0-2.9 (2.4)	55-73
10-19	20-85 (42)	2.3-3.2 (2.8)	"
20-29	20-75 (46)	2.4-3.3 (2.8)	"
30-39	15-80 (44)	2.3-3.4 (2.8)	"
40-49	15-65 (36)	2.4-3.5 (2.8)	"
50-59	15-70 (28)	2.6-3.6 (3.1)	"
60-69	10-50 (26)	2.8-3.7 (3.2)	52-68
70-	10-45 (20)	2.8-3.8 (3.2)	"

Median (sensory-orthodromic)/wrist (48)

I. Position of Patient
   A. Patient is supine with upper extremity supinated and extended at side.
   B. Upper extremity is supported by the bed at all times.

II. Equipment
   A. 2 disc electrodes (G1 active, G2 reference)
   B. 1 ground (G0)
   C. 2 sensory clip stimulatory electrodes (S1 cathode, S2 anode)

III. Machine Settings
   A. Sweep speed (ms/div)—1 to 2
   B. Gain (μv)—5 to 20
   C. Filters—32 (Hz), 1.6 (KHz)

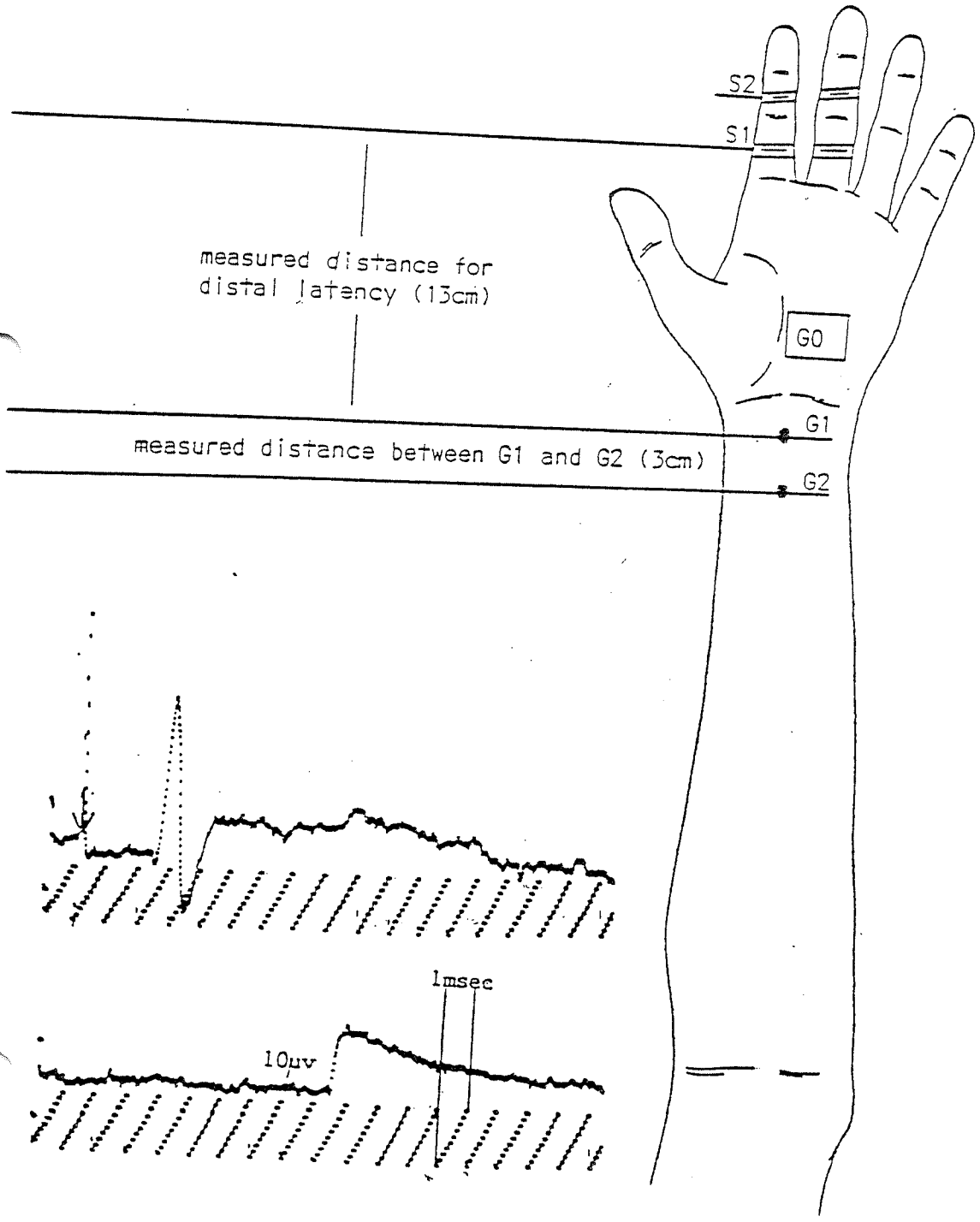
IV. Electrode Placement
   A. G0 (ground)—palm of hand between G1 and S1
   B. G1 (active)—between the flexor carpi radialis tendon and the palmaris longus tendon, 3 to 5 cm proximal to the distal wrist crease.

*Median sensory conduction velocities should: (1) be in the normal range and (2) be the same or faster than the median motor conduction velocities.

MEDIAN (sensory-orthodromic) / wrist

age = 45

Stimulation Site	Amp. μv	Latency msec	Dist. cm
index finger or middle finger	25	3.0	13



C. G2 (reference)—3 cm proximal to G1 between the flexor carpis radialis and the palmaris longus tendons.

V. Stimulation Sites and Measurements

A. Finger (Index or Middle):

1. Stimulate—S1, midportion of the proximal phalanx of either the index or middle fingers: S2, midportion of the middle phalanx of the same finger as G1.
2. Measure—distance from S1 to G1 in a straight line. On adults use a distance of 13 cm if possible.

VI. Calculations

A. Distal Latency—Calculate from the shock artifact to the peak of the negative deflection of the distal response.

B. Amplitude—Calculate from the shock artifact to the peak of the negative deflection of the distal response.

VII. Variations and Pitfalls

A. If distance other than 13 cm is used, add or subtract 0.2 msec for each cm difference.

B. Cold may cause a prolonged distal latency with a normal amplitude.

VIII. Normal Values (48)

AGE	AMPLITUDE μv	DISTAL LATENCY msec
16-65	10-60	2.1-3.4
over 65	8-26	2.5-3.8

Median (sensory-palmar)/wrist (12, 48) Orthodromic

I. Position of Patient

A. Patient is supine with upper extremity supinated and extended at side.

B. Upper extremity is supported by the bed at all times.

II. Equipment

A. 2 disc electrodes (G1 active, G2 reference)

B. 1 ground (G0)

C. 1 bipolar stimulator (S1 cathode, S2 anode)

III. Machine Settings

A. Sweep speed (ms/div)—1 to 2

B. Gain (μv)—5 to 20

C. Filters—32(Hz), 1.6(KHz)

IV. Electrode Placement

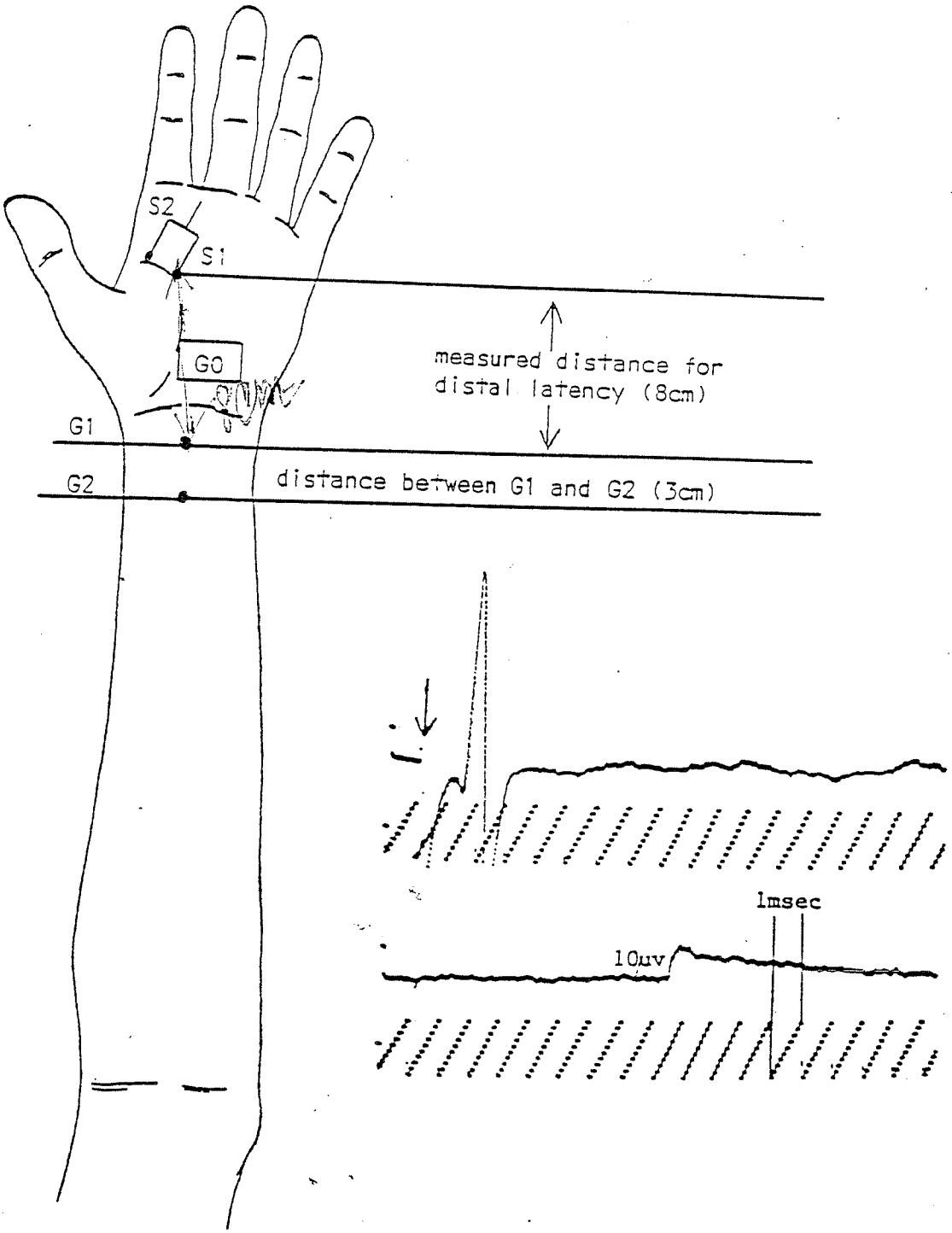
A. G0 (ground)—palm of hand between G1 and S1.

B. G1 (active)—between the flexor carpi radialis tendon and the palmaris longus tendon, 3 to 5 cm proximal to the distal wrist crease.

MEDIAN (sensory-palmar) / wrist

age = 38

Stimulation Site	Amp. μv	Latency msec	Dist. cm
palm	60	2.0	8.0



C. G2 (reference)—3 cm proximal to G1 between the flexor carpi radialis and palmaris longus tendon.

V. Stimulation Sites and Measurements

A. Palm:

1. Stimulate—S1, on the thenar crease at the second metacarpal interspace. S2, distal to S1 along the thenar crease.
2. Measure—distance from S1 to G1 in a straight line. On adults use a distance between 7 to 9 cm.

VI. Calculations

A. Distal Latency—Calculate from the shock artifact to the peak of the negative deflection of the distal response.

B. Amplitude—Calculate from baseline to the peak of the negative deflection.

VII. Variations and Pitfalls

A. Excessive shock artifact caused by the use of short distances may cause a poor takeoff.

B. Cold may cause a prolonged distal latency with a normal amplitude.

VIII. Normal Values (12, 48)

A. Normally, amplitudes will be greater than 40 μv.

B. Maximal peak latency is 2.2 msec.

C. Median palmar latencies should be no more than 0.2 msec longer than the ipsilateral ulnar palmar latencies for the same distance.

D. Median palmar latencies should be no more than 0.15 msec longer than the contralateral median palmar latencies.

Musculocutaneous (motor)/biceps brachii (10, 48, 50)

I. Position of Patient

A. Patient is supine with upper extremity supinated and extended at side.

B. Upper extremity is supported by the bed at all times.

II. Equipment

A. 2 large disc or small ground electrodes (G1 active, G2 reference)

B. 1 ground (G0)

C. 1 bipolar stimulator (S1 cathode, S2 anode)

III. Machine Settings

A. Sweep speed (ms/div)—2 to 5

B. Gain (mv)—1 to 10

C. Filters—1.6(Hz), 8(KHz)

IV. Electrode Placement

A. G0 (ground)—upper arm, between G1 and S1.

B. G1 (active)—over the belly of the muscle, biceps brachii.