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Phrenic Nerve Motor Conduction Study

Patient Position: The patient should be positioned supine with no pillows under the neck for this study.

Skin Prep: Wipe with alcohol, temperature check.

Settings:
Sweep Speed: 10 msec/div
Sensitivity/Gain: 0.5 mV/div.
Filters: 2Hz- 10 kHz

Recording: The diaphragm CMAP is recorded from ipsilateral surface electrodes G1 & G2.

Active: The active surface electrode (G1) is placed two fingerbreadths (5 cm) above the xiphoid process.

Reference: The reference electrode (G2) is placed 16 cm away from G1 over the anterior costal margin

Ground: The ground is placed between the stimulating and recording electrodes.

Stimulation:

The phrenic nerve is stimulated between sternal and clavicular heads of the SCM, just above the clavicle stimulator oriented medially. 0.2 ms stimulus duration is used. Alternative stimulation site is at the posterior border of the sternomastoid muscle. The cathode is placed inferior to the anode approximately 3 cm above the clavicle.

Measurements:

Distance between cathode and active recording electrode taking the shortest distance possible rather than following the course of the nerve.
Latency amplitude and duration for CMAP recording.

Reference Values:

Author	Distal distance (cm)	Recording	Amplitude (B-N) (µV)	Distal Latency (ms)
Markand ON, Kincaid J.C, Pourmand..	Variable	Diaphragm	597 $\pm$ 139 > 320	6.3 $\pm$ 0.8 $\leq$ 8.0

Key Points:
Do not perform this study in the intensive care unit in patients who have an external pacemaker (risk of current spread to the heart); caution if an internal jugular catheter, implanted cardiac pacemaker, or cardioverter-defibrillator is nearby.
Technical problems identified are inadvertent brachial plexus stimulation causing movement of the arm and shoulder and a volume conducted compound action potential is recorded from chest wall muscles. In this case the CMAP has an initial positive phase and a much shorter latency. To avoid this one may need to apply firm pressure while holding the stimulator above the clavicle oriented medially, or to reduce stimulus duration and intensity.
Observe abdominal wall muscle movement when diaphragm is contracting causing a brisk inspiration sound similar to hiccup. Contrary, if the stimulation results in arm/shoulder movement then brachial plexus is stimulated, not phrenic nerve.
Amplitudes are compared side to side. Conduction times as opposed to conduction velocities are preferred as it is difficult to accurately measure the neural segment.
Difficult study to perform in obese individuals.

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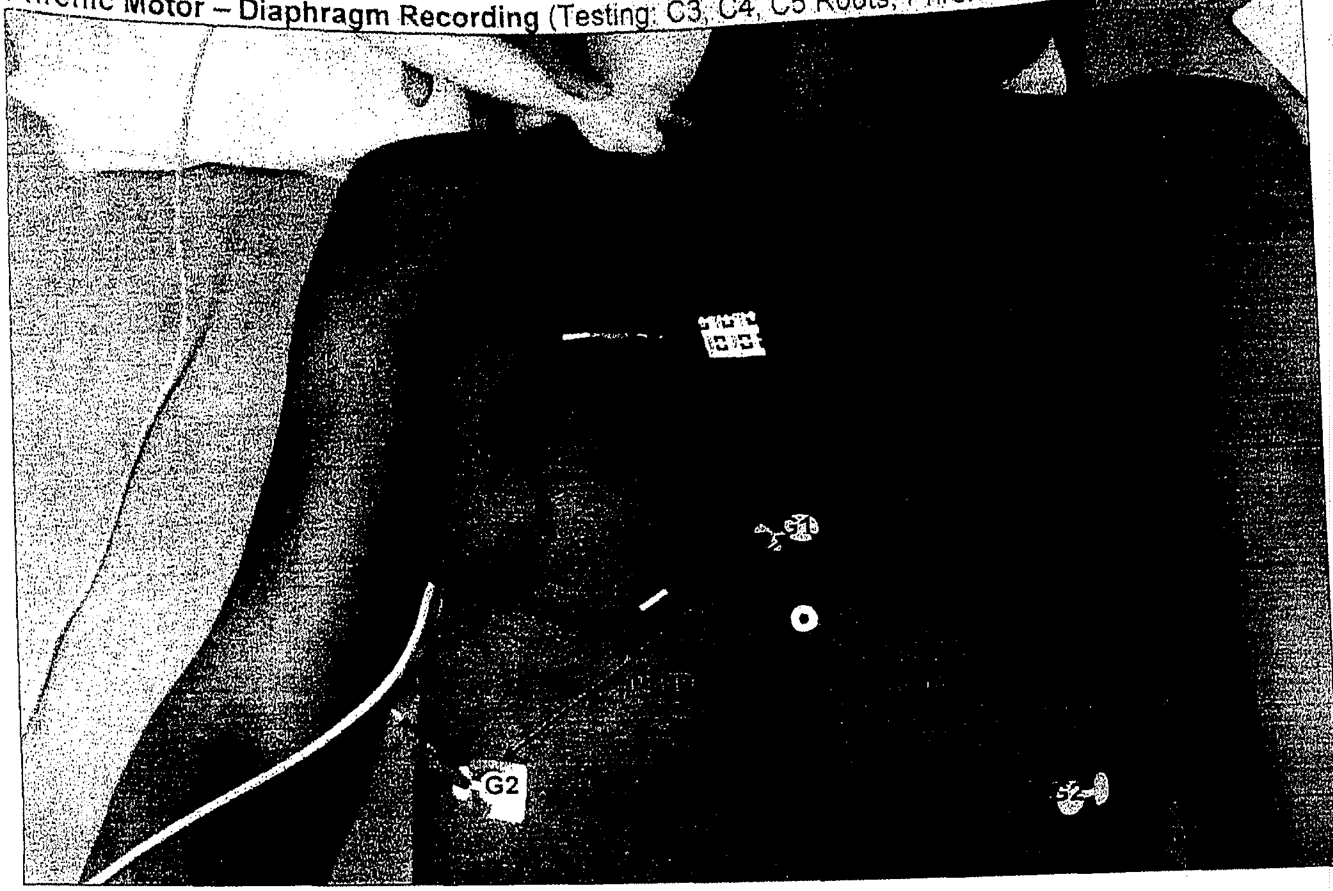
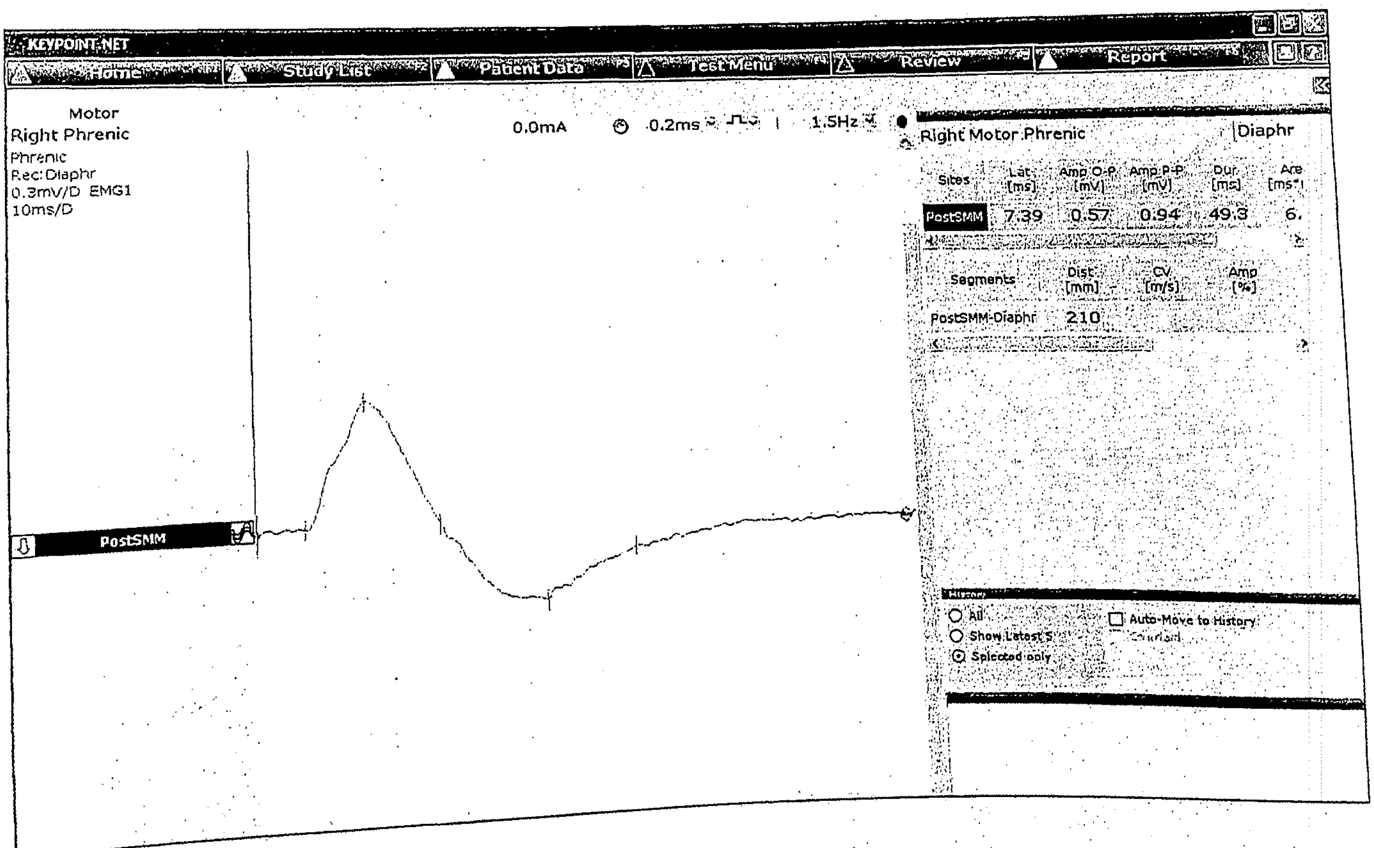
Phrenic Motor – Diaphragm Recording (Testing: C3, C4, C5 Roots, Phrenic Nerve)





left sides were studied. Repeat studies were performed in 23 subjects, 5 days to 6 weeks after the first study. Needle electromyography of the diaphragm was also performed and the results will be reported separately. All subjects gave informed consent and the study protocol was approved by the university ethics committee.

Their mean (± standard deviation) height was 169.2 ± 10.0 cm, weight was 72.2 ± 12.6 kg, and chest circumference at the level of the xiphoid process was 97.5 ± 6.1 cm. Peak expiratory flow rate (PEF), forced expiratory volume in 1 s (FEV_1), and forced vital capacity (FVC) were measured with a spirometer (Pocket spirometer, Micro Medical Instruments, Kent, UK). Percentage body fat was determined from published tables[1] using skin-fold thickness measured with a caliper (Skinfold caliper, Lafayette Instrument Co., IN).

Phrenic Nerve Conduction Studies. Subjects were studied lying supine in a warm room. The phrenic nerve was stimulated at the posterior border of the sternomastoid muscle in the supraclavicular fossa, just above the clavicle, using bipolar surface electrodes with the cathode at a lower level.[2] A constant current stimulator delivered square-wave pulses of 0.1-ms duration. Inadvertent brachial plexus stimulation was detected by arm movement; subject reporting of arm paraesthesia; and a short latency, low amplitude, initially positive response.[2] Almost pure phrenic nerve stimulation can be obtained with slight repositioning of the stimulus, usually to a more medial position, which produces a "hiccup" sensation and an unvarying waveform associated with little or no limb movement. The recording was rejected if electrocardiogram artifacts, which cause prolonged (<50 ms), high amplitude deflections, were encountered and the stimulus was repeated. Two supramaximal responses were obtained and average values were calculated. Filters were set at 5 Hz to 5 kHz (−3 dB down).

The diaphragmatic compound muscle action potential (CMAP) was recorded with self-adhesive surface electrodes (2.5 × 2.5 cm) (3M, St. Paul, Minnesota) applied 5 cm superior to the tip of the xiphoid process (XP) as the G_1 electrode and to the costal margin (CM) 16 cm from the XP electrode as the G_2 electrode. The position of the CM electrode usually corresponds to the seventh intercostal space. In all recordings, a negative potential at the first electrode (G_1) or a positive potential at the second electrode (G_2) results in an upward deflection. The distance from the stimulating cathode to the XP electrode was measured. Four measurements of the diaphragmatic CMAP were made: latency was determined from the onset of the negative peak; amplitude from the baseline to the negative peak; NP area; and duration from the negative peak onset to return to baseline.

Further studies were conducted in 3 subjects. Monopolar recordings were obtained with the opposite knee (KN) a reference electrode with XP–KN and CM–KN derivations. Recordings were also made from the lateral chest wall (LCW) at the level of the xiphoid process in the anterior axillary line with LCW–KN and LCW-below umbilicus (UM) montages.[22] The effects of different lung volumes were investigated by recordings at maximum inspiration [total lung capacity (TLC)], quiet expiration [functional residual capacity (FRC)], and maximum forced expiration [residual volume (RV)].

Data Analysis. Relationship between various anthropometric measures (age, chest circumference, etc.) and the measured latencies, amplitudes, NP areas, and durations were analyzed using simple and multiple regression analysis. The paired *t*-test was used to detect right–left differences and the unpaired *t*-test was used to detect sex and non-smoker/ex-smoker differences. Differences were considered statistically significant if $P \leqslant 0.01$.

RESULTS

Both phrenic nerves could be stimulated easily and without undue discomfort in all 25 subjects. The current required for supramaximal stimulation was always less than 90 mA with a pulse duration of 0.1 ms, and was less than 50 mA in the majority of the studies.

Table 1 shows the latencies, amplitudes, NP areas, and durations obtained. Mean plus 2 standard deviations (SD) is used to define the normal limit of latency and duration. Because of the non-Gaussian distribution of amplitude, the lower limit

Table 1. Phrenic nerve conduction—normal values (n = 50).*

Measurement	Mean ± SD	Range	Suggested normal limit
Latency (ms)	6.54 ± 0.77	5.5–8.4	<8.1†
Amplitude (μV)	660 ± 201	301–1198	>300‡
NP area (μVms)	7.28 ± 2.09	4.0–12.8	>4.0‡
NP duration (ms)	19.4 ± 2.7	13.4–24.1	<25†

*Normal values determined from 50 phrenic nerves in 25 normal subjects.
†Upper limit of normal calculated as + 2 SD.
‡ Lower limit of normal based on distribution of normative data.

Table 3. Differences between first and second study (*n* = 46).*

Measurement	Mean ± SD	Range	Mean + 2 SD
Latency (ms)	0.28 ± 0.23	0–0.9	0.74
% difference†	4.3 ± 3.2	0–11.3	10.7
Amplitude (μV)	66.3 ± 65.3	1.5–305	196.9
% difference†	10.9 ± 10.5	0.3–40	31.9
NP area (μVms)	0.86 ± 0.75	0.04–3.5	2.36
% difference†	8.9 ± 8.1	0.8–38	25.1
NP duration (ms)	1.53 ± 1.33	0.1–5.75	4.19
% difference†	7.6 ± 6.3	0.4–29.1	20.2

*Forty-six phrenic nerves from 23 normal subjects.
†Percentage difference calculated as [absolute value of (first − second study)]/(mean of first and second study) for each phrenic nerve.

DISCUSSION

In our experience, percutaneous phrenic nerve stimulation is not technically difficult, causes little discomfort to the subject, and is preferable to needle stimulation which is cumbersome and potentially hazardous. We were able to locate both phrenic nerves in all subjects tested. Several groups also came to similar conclusions.[13,15,22]

Our method is modified from that of Markand et al.[13] In our experience, percutaneous localization of the phrenic nerve is easier close to the clavicle than at the level of the upper border of the thyroid cartilage. We also found rib counting difficult and inaccurate in obese subjects and in the

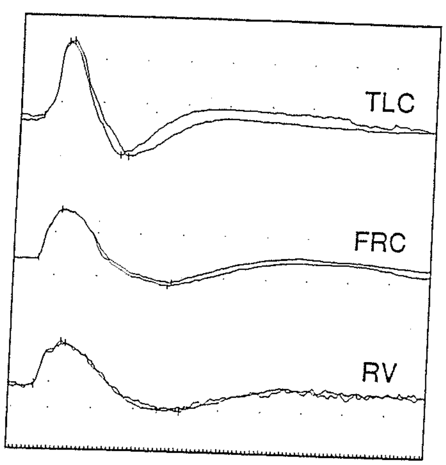


FIGURE 3. Effects of variation in lung volumes on diaphragmatic CMAP recorded with XP–CM derivation in a representative subject. Two supramaximal responses were obtained at each lung volume. The amplitude increases and the duration decreases with higher lung volume. Abbreviations: TLC = total lung capacity; FRC = functional residual capacity; RV = residual volume. Calibration: 10 ms and 500 μV per division.

intensive care units where monitoring lines, catheters, or chest tubes are frequently in place. We therefore placed the costal margin electrode at a standard distance of 16 cm from the xiphoid electrode. Our preliminary studies showed that the maximum amplitude is usually obtained at this distance with little variation within several centimeters.

The positive potential recorded with CM–KN derivation and the negative potential recorded with XP–KN derivation can be explained using the leading/trailing dipole model for far-field potentials in muscle.[7] The phrenic nerve enters the diaphragm much closer to the XP electrode than the CM electrode.[14] With CM–KN derivation, the leading dipole detected by the KN electrode is extinguished before the leading dipole for the CM electrode, leading to an initially positive response. The reverse occurs with XP–KN derivation, leading to an initially negative response. The effect of different lung volumes on the diaphragmatic CMAP may be explained by the movement of the diaphragm. The diaphragm is a dome-shaped structure which flattens during inspiration. Therefore, with inspiration, the main muscle mass moves closer to the CM electrode and away from the LCW electrode, which is placed higher, at the level of the xiphoid process. Besides, according to the theory of volume conduction, the amplitude is proportional to the angle the moving dipole subtends at the recording electrode.[6] In quiet respiration, the moving dipole approaches the CM electrode at an oblique angle due to the dome shape of the diaphragm. The angle the dipole subtends increases as the diaphragm flattens during inspiration (Fig. 4).

The mean latency (6.54 ms) obtained is considerably shorter than that reported by Newsom-Davis[16] (7.7 ms), MacLean and Mattioni[12] (7.44 ms), Markand et al.[13] (right 7.77 ms, left 7.74 ms), McKenzie and Gandevia[14] (right 7.68 ms, left 7.92 ms), and slightly shorter than that of Mier et al.[15] (right 6.94 ms, left 6.61 ms) and Swenson and Rubenstein[22] (right 6.87 ms, left 6.72 ms). The difference is most likely related to variations in the stimulation site. Newsom-Davis[16] and Markand et al.[12] stimulated at the upper border of the thyroid cartilage, MacLean and Mattioni[12] used needle electrodes at the level of the thyroid cartilage. McKenzie and Gandevia[14] and Meir et al.[15] stimulated at the level of the cricoid cartilage. We stimulated at a lower level and close to the clavicle, similar to the technique of Swenson and Ruben-

CV Motor | Right ~~Axillary~~ Phrenic Left | MARIE A. REMEDIOS (208) 3373 01/20/00

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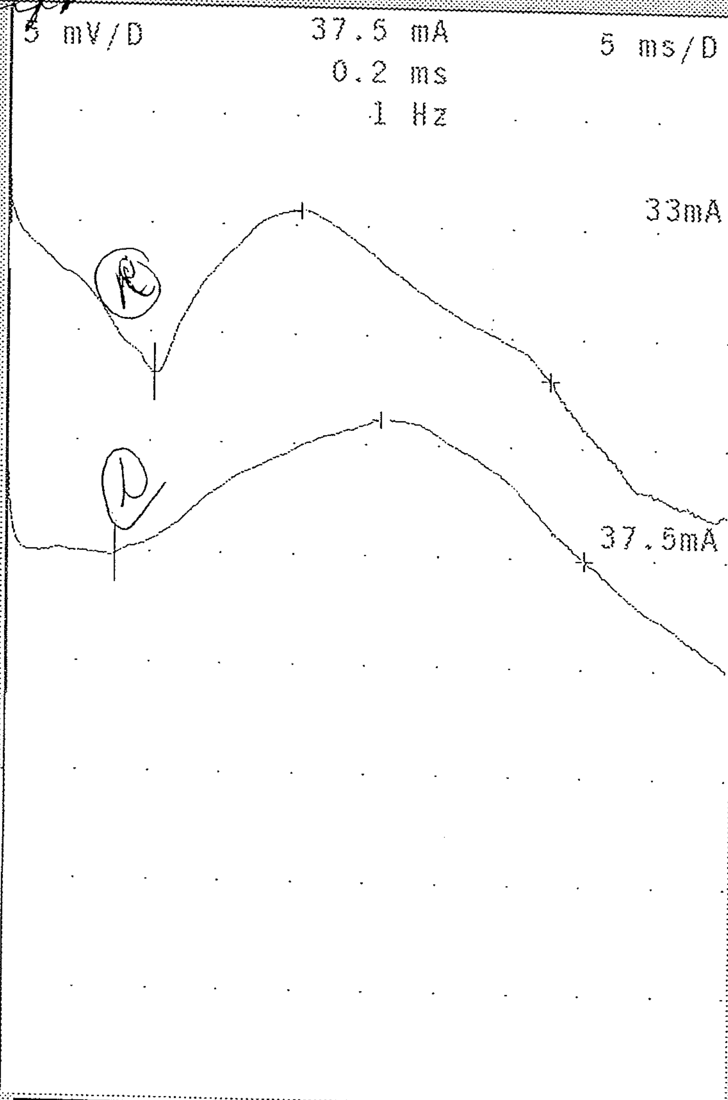

Dist

Pos. 1

Pos. 2

Dist

Pos. 3

Pos. 4

Pos. 5

TEMP

MANUAL

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dLAT/CV	AMP	AREA	DUR
10.3	7.5	117.5	27.4
	-17 %	1 %	19 %
7.6	6.2	118.4	32.5

Amp Nl > 300 μV = > .3 mV

H-reflex | Edit texts

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