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Original Article

Difference between the Right and Left Phrenic Nerve Conduction Times, Latency, and Amplitude

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We studied phrenic nerve conduction times in 90 phrenic nerves of 45 normal subjects. The phrenic nerve was stimulated at the posterior border of the sternomastoid muscle in the supraclavicular fossa, just above the clavicle, with bipolar surface electrodes. For recording, positive and negative electrodes were placed on the xiphoid process and at the eighth intercostal bone-cartilage transition, respectively. We studied both the right and left sides to determine whether there was any difference between the two sides. The mean onset latency (± SD) of the right compound muscle action potentials (CMAPs) (5.99 ± 0.39 msec) was significantly shorter than that of the left CMAPs (6.45 ± 0.50 msec). The mean peak latency was significantly shorter in the right CMAPs (10.22 ± 1.33 msec) than the left CMAPs (12.48 ± 2.02 msec). The mean (± SD) amplitude was significantly lower in the left CMAPs (0.42 ± 0.11 mV) than the right CMAPs (0.49 ± 0.10 mV). The difference between the length of the nerve on the right and left sides might have affected the difference in latency between the two sides.

Key words: phrenic nerve, right left difference, healthy subject, nerve conduction

The phrenic nerve may be impaired during thoracic surgery such as lung transplantation, and the diagnosis of a phrenic nerve injury may then be necessary. Phrenic nerve conduction studies can be invaluable in establishing the diagnosis of a phrenic nerve injury, determining its severity, and following the disease progression. However, phrenic nerve conduction studies are still not widely used, as they are often perceived as technically difficult, inaccurate, time-consuming, and uncomfortable for the patient [1, 2]. We conducted the present study to (1) determine the normal data of the phrenic nerve diaphragmatic compound muscle action potential (CMAP), and (2) investigate the difference between the right and left phrenic nerve CMAPs in healthy adult males.

Subjects and Methods

Subjects. We studied 45 healthy male volunteers aged 20-40 (mean 25.0) years. None of the subjects had neurological or respiratory dysfunction. Their mean (± standard deviation) height was 170.8 ± 4.8 cm, and they weighed 62.6 ± 6.2 kg. The subjects were recruited mainly from hospital personnel. Informed consent was obtained from each subject after they received a thorough explanation of the purpose and procedure of the study. The protocol was approved by the Okayama University Ethics Committee (no. 1702-028).

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nerve conduction studies were performed on Keypoint® EMG equipment (Medtronic Dantec, Copenhagen, Denmark). For the examination, the subject was in the supine position in a warm room. The phrenic nerve was stimulated using bipolar surface electrodes placed at the posterior border of the sternomastoid muscle in the supraclavicular fossa immediately above the clavicle. For recording purposes, positive and negative electrodes were placed on the xiphoid process and at the eighth intercostal bone cartilage transition, respectively (Fig. 1).

A constant current stimulator delivered square-wave pulses of 0.1-msec duration. Filters were set at 5 Hz to 5 kHz (−3dB down). Three measurements of the diaphragmatic CMAP were made: (1) the onset latency (msec) was determined from the onset of the negative peak; (2) the peak latency (msec) was determined from the negative peak; and (3) the amplitude from the baseline to the negative peak. Both the right and left sides were studied for the identification of any differences between the 2 sides.

Data analysis. The paired *t*-test was used to detect right-left differences. Differences were considered significant when $p < 0.05$.

Results

Both phrenic nerves could be stimulated easily and without intolerable discomfort in all 45 subjects. The intensity required for supramaximal stimulation was always < 50 mA with rectangular pulses of 0.2 msec. As shown in Table 1, the mean onset latency (± SD) of the right CMAPs (5.99 ± 0.39 msec) was significantly shorter than that of the left CMAPs (6.45 ± 0.50 msec) ($p < 0.01$). The mean peak latency was significantly shorter in the right CMAPs (10.22 ± 1.33 msec) than the left CMAPs (12.48 ± 2.02 msec) ($p < 0.01$) (Fig. 2). The mean (± SD) amplitude was significantly lower in the left CMAPs (0.42 ± 0.11 mV) than the right CMAPs (0.49 ± 0.10 mV; $p < 0.01$) (Fig. 3).

The distance between the cathode and the anode of the recording electrodes was 13.11 ± 1.42 cm. The distance between the recording electrode and the stimulation electrode was 23.78 ± 2.01 cm.

Discussion

The diaphragm plays an important role in sustaining the body's breathing, and it is thus very important to understand and carry out techniques for testing the diaphragm. The diaphragm is responsible for > 70% of the body's respiratory muscle function, and the phrenic nerve controls the diaphragm. The CMAP onset latency has a well-established role in studies of phrenic nerve conduction, and it is very useful for the detection of demyelination of the phrenic nerve [3]. Phrenic nerve

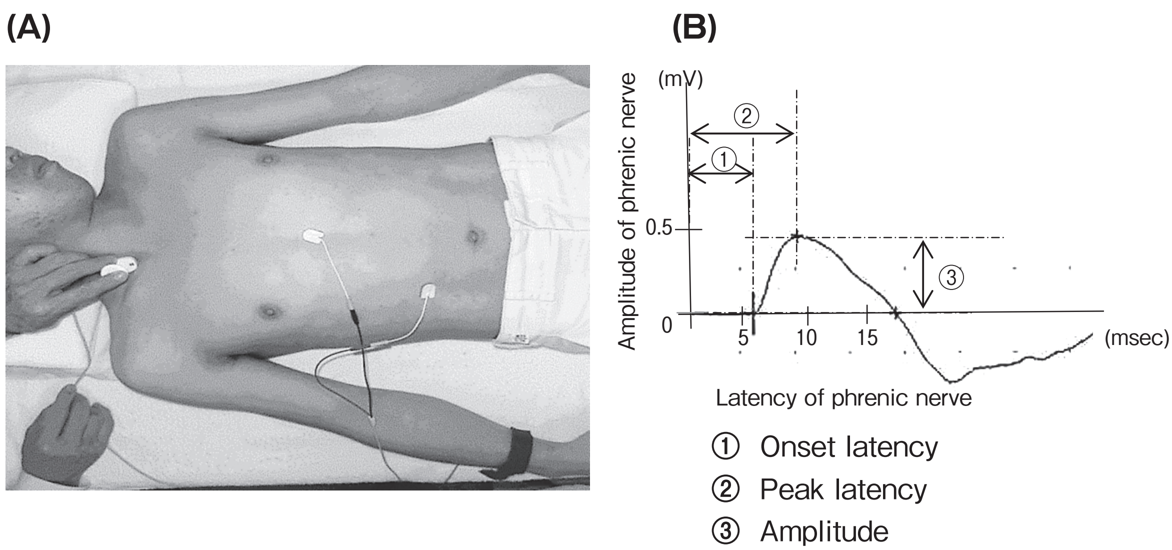

Fig. 1 Method of phrenic nerve conduction studies. A, Positions of the stimulation and recording electrodes for phrenic nerve conduction studies; B, Conduction in the phrenic nerve showing the uniform shape and amplitudes of the compound muscle action potential (CMAP) for stimulation at the posterior border of the sternomastoid muscle.

Table 1 Latency and amplitude differences between the right and left phrenic nerves

		Right	Left	*p*
This study	Onset latency, msec	5.99 ± 0.39	6.45 ± 0.50	< 0.01
	Peak latency, msec	10.22 ± 1.33	12.48 ± 2.02	< 0.01
	Amplitude, mV	0.49 ± 0.10	0.42 ± 0.11	< 0.01
Imai *et al*. [7]	Latency, msec	6.80 ± 0.72	6.82 ± 0.80	n.s.
	Amplitude, mV	0.44 ± 0.18	0.37 ± 0.17	n.s.
Swenson *et al*. [8]	Latency, msec	6.28 ± 0.55	6.30 ± 0.48	n.s.
	Amplitude, mV	0.35 ± 0.12	0.35 ± 0.19	n.s.

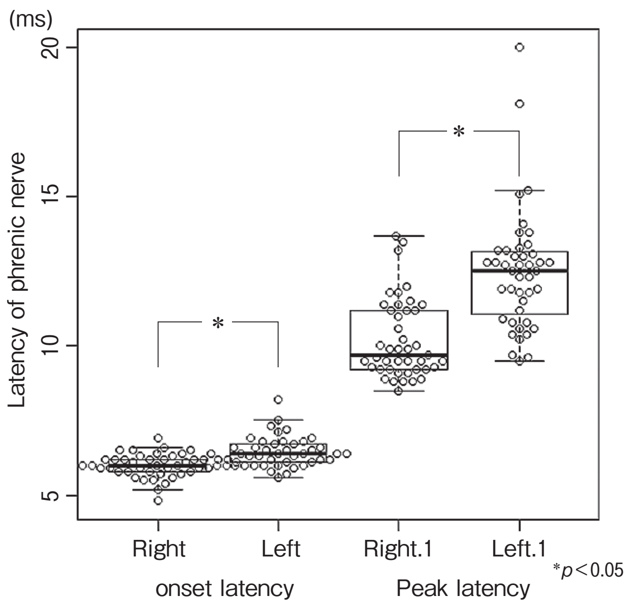

Fig. 2 The differences in latency between the right and left phrenic nerves.

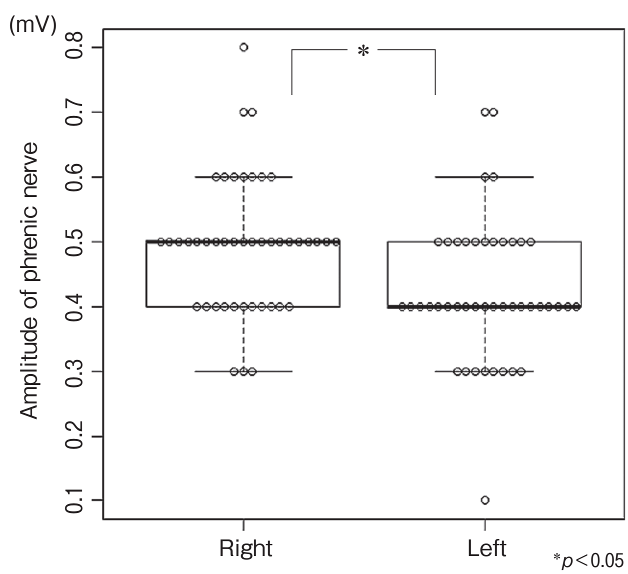

Fig. 3 The differences in amplitude between the right and left phrenic nerves.

conduction studies have been applied to amyotrophic lateral sclerosis (ALS) and Guillain-Barre syndrome, both of which are life-threatening due to respiratory muscle dysfunction; the results indicated a decrease in the amplitude and distal latency prolongation of the CMAP [4,5].

Komori reported that, as ALS progresses, one indication that respiratory support (such as noninvasive positive pressure respiratory support) for a patient should be started is when M waves become polymorphic or both the right and left phrenic nerve amplitudes become ≤ 0.2 mV [6]. In the present study, the right-to-left differences in onset and peak latencies were significant. However, previous studies reported different results. Imai *et al.* stated that the mean latency was almost the same for the left and right diaphragmatic action potentials in 132 nerves of all subjects, and he noted that a left-right difference may be useful in diagnosing a unilateral phrenic lesion [7]. Swenson *et al.* studied 20 normal subjects and reported the ease of application and good side-to-side agreement for distal compound motor action potential (DCMAP) latencies [8] (Table 1).

In a phrenic nerve conduction study, Komori set the onset latency and amplitude of phrenic nerve as measurement parameters [6]. In healthy individuals, differences in amplitude between the left and right phrenic nerve action potentials are usually not significant, and both sides of the diaphragm function together as the inspiratory muscle. Komori used the average amplitude of the 2 sides in correlation with respiratory function [6]. Standard textbooks and the relevant literature have offered detailed anatomic descriptions of the cervical part of the phrenic nerve [9]. However, there is very little anatomic literature on the thoracic part of the phrenic nerve and its precise relationship with the adjacent structures [10]. In the present study, the thoracic part of the phrenic nerve was observed to possess some morphological characteristics.

The best approach will vary among subject populations and may vary between the 2 sides of an individual subject due to asymmetry of the phrenic nerves [11]. Su Jiang *et al.* dissected ten fresh adult cadavers and observed that the full length of the phrenic nerve was 24.6 ± 1.7 and 30.6 ± 1.8 cm on the right and left sides, respectively [10]. In both cases mentioned above, the lengths of the phrenic nerve on the right side could be explained by the two-intercostal-space elevation of the diaphragm due to the liver on the right side of the body [10, 11].

The phrenic nerves arise from C4 with accessory branches from C3 and C5. It lies on the anterior scalene muscle and then passes anterior to the hilum of the lung to the diaphragm, with some fibers continuing into the peritoneum. The paths of the left and right phrenic nerves are not exactly the same. The left phrenic nerve is bent around the rear of the apex of the heart, but reaches the diaphragm to draw a concave bow to the front. In contrast, the right phrenic nerve is on the outer surface of the right arm's head vein, and then runs in contact with the outer surface of the superior vena cava, reaching forward and arriving at the diaphragm on the outside of the vena cava hole. The left phrenic nerve is longer than the right phrenic nerve. The difference between the lengths of the right and left nerves might have affected the difference between the latencies of the right and left sides. The onset latencies obtained in our study (5.99 ± 0.39 and 6.45 ± 0.50; Table 1) were considerably shorter than those reported by Chen (6.54 msec) and Resman-Gaspersc (6.55 msec). We speculate that the differences in the onset latencies might be affected by the physique of each subject and the inspection methods used.

The subjects in this study were limited to healthy males aged 20-40 years old. In future investigations we will include subjects from several age groups and female subjects in order to further elucidate differences between the left and right phrenic nerves.

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