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Phrenic Nerve Conduction Studies in Healthy Korean

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The assessment of diaphragmatic function has received increasing attention in recent decades because of successful clinical application of the electrophrenic pacemaker. Knowledge of the normal value of the phrenic nerve conduction latency according to Korean physical characteristics may be helpful when choosing electrophrenic respiration candidates and for evaluating diaphragmatic function postoperatively. Therefore in this study we have put the emphasis on obtaining the mean value of the phrenic nerve conduction latency in 18 healthy Korean adults and have correlated the effect of the intercathodal distance and the height of the subject with the conduction latency. As a result the mean conduction latency for the phrenic nerve was 7.10 msec (SD 0.14) and the mean intercathodal distance was 33.2 cm (SD 0.41). Significant positive correlations of intercathodal distance with conduction latency and with subject height were found.

Key Words: Phrenic nerve conduction latency, intercathodal distance

In a great variety of causes of diaphragmatic paralysis it is of importance to determine the cause of paralysis and it is also valuable to obtain a reliable and qualitative estimate of recovery from paralysis including the effect of the treatment.

The assessment of diaphragmatic function has received increasing attention in recent decades because of successful clinical application of the electrophrenic pacemaker. The investigation that have been used to evaluate diaphragmatic function are serial pulmonary function tests, X-ray studies, and studies of clinical signs and symptoms. Neurophysiological parameters have been most useful for estimating phrenic nerve as well as diaphragmatic function.

Paralysis of the diaphragm may occurs as a complication of various neurologic diseases such as poliomyelitis (Sarnoff *et al.*, 1950; Glenn *et al.*, 1973), polyradiculopathy (Davis, 1967), herpes zoster (Halpern and Covner, 1949), and progressive spinal muscular atrophy (Parhad *et al.*, 1978). Cases of diaphragmatic paralysis have been reported following chest or neck trauma resulting in damage in phrenic nerve (Schifrin, 1952; Bingham, 1954). Diaphragmatic paralysis has also been associated with Erb-Duchenne paralysis in the newborn infant (Radecki and Tomatis, 1976). Spontaneous paralysis of the diaphragm occurs as a result of phrenic nerve involvement by tumor (Rees-Jones, 1944; Riley, 1962). In patients with high spinal cord injury above C4, there is the likelihood of denervation of the phrenic nerve, resulting in considerable degree of diaphragmatic paralysis (Kottke *et al.*, 1982).

Artificial respiration combined with electrical stimulation of the phrenic nerve was suggested by Hufeland in 1783 (Schechter, 1970). In 1937, Waud reported that rabbits could be maintained in a satisfactory respiration condition for hours by rhythmic electrical stimulation of the phrenic nerve. Sarnoff and associates, in 1948 through 1950, experimented with several other species of animal and noted that submaximal electrical stimulation of the phrenic nerve could effect adequate gaseous exchange, and the feasibility of electrophrenic stimulation in man for the first time. In 1957 Draper *et al.* using surface electrodes mounted on an esophageal tube, succeeded in obtaining records of action potentials from the human diaphragm. In his work Taylor (1960) found it very satisfactory to record action potentials from the

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diaphragm with needle electrodes inserted below the 9th or 10th ribs in the mid-axillary line. In 1967 Davis described the first use of surface electrodes to record action potentials from the diaphragm and reported normal value of the phrenic nerve conduction latency. In his study the subjects ranged from 20 to 61 years of age and included those whose nerve conduction latency was supposedly prolonged. Although many techniques have been introduced to assess normal neurophysiologic function of the phrenic nerve, these were done already in other countries (Davis, 1967; MacLean and Mattioni, 1981).

In the present study we have put the emphasis on obtaining the mean value of the phrenic nerve conduction latency in healthy Korean adults and have correlated the effect of the intercathodal distance and the height of the subject with the conduction latency.

MATERIAL AND METHOD

Thirty six phrenic nerves were examined in eighteen volunteers with no history of neurological deficit. They ranged in age from 23 to 47 years. Their average height was 170.3 cm with a range of 150 to 179 cm.

Phrenic nerve stimulation tests were performed using TECA Model M electromyograph equipment in a quiet room with a temperature of 24°C. Surface recording electrodes were placed on the chest wall as Davis (1967) described: 4 cm apart in the eighth or between eighth and ninth intercostal spaces with the anterior electrode at the anterior axillary line. The phrenic nerve was stimulated percutaneously placing the cathode at the posterior border of the sternocleidomastoid muscle corresponding to the level of the upper edge of the thyroid cartilage and the anode over the manubrium sterni. The ground electrode was applied over the upper chest wall between the stimulating and the recording electrodes. A square wave of supramaximal intensity impulse with 0.5 to 1.0 msec duration at a rate of one per second was delivered to the phrenic nerve. The response was photographed and the latency was calculated from the stimulus artifact to the first well-defined negative peak of the motor response. The intercathodal distance was measured from the stimulating to the recording sites.

Comparison was made of the mean value of the conduction latency with Davis's results to try and create confidence in clinical application.

RESULTS

The summary of data on age, sex and height were

Table 1. Age and sex distribution

Age (Yrs)	Sex: Male	Sex: Female	Total
0 – 9	–	–	–
10 – 19	–	–	–
20 – 29	15	–	15
30 – 39	–	–	–
40 – 49	–	3	3
50 –	–	–	–
Total	15	3	18

Height: mean = 170.26 cm (SD = 7.66)

Table 2. Conduction latencies of phrenic nerve

	Tested side	Conduction latency (msec)	n	t-value
Rt.	Mean	7.23	18	0.85
	S.D.	0.78		
Lt.	Mean	6.95	18	
	S.D.	0.92		
Both	Mean	7.10	36	
	S.D.	0.14		

$t_{0.05}$ (df 34) = 1.69
Mean skin temperature = 34.7°C

Table 3. Intercathodal distances of phrenic nerve

	Tested side	Intercathodal distances (cm)	n	t-value
Rt.	Mean	33.3	18	0.38
	S.D.	2.52		
Lt.	Mean	33.1	18	
	S.D.	6.85		
Both	Mean	33.2	36	
	S.D.	0.41		

$t_{0.05}$ (df 34) = 1.69
Mean skin temperature = 34.7°C

Table 4. Comparison of the mean of the phrenic nerve conduction latencies between two studies

	Mean (msec)	S.D.	n	t-value
Davis	7.7	0.8	22	2.24
YUMC	7.1	0.14	36	

$t_{0.05}$ = 2.42, d.f. = 56

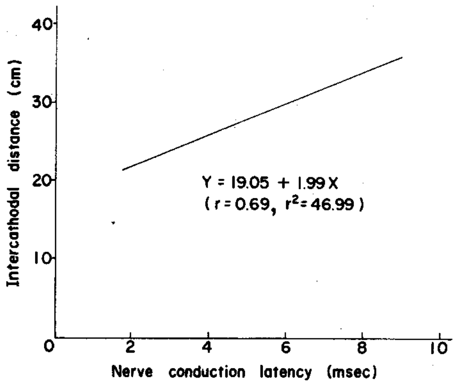

Fig. 1. *The relationship between phrenic nerve conduction latency and intercathodal distance. The regression line is shown.*

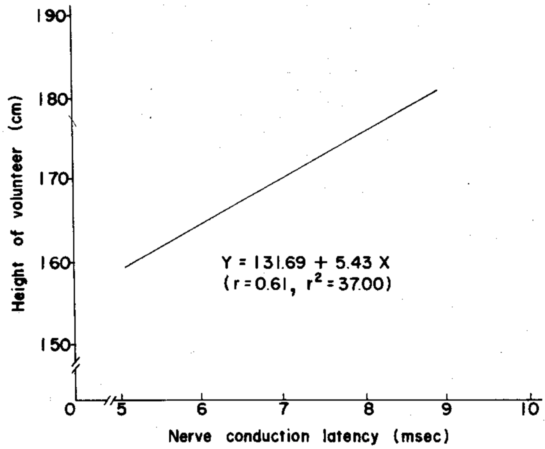

Fig. 3. *The relationship between phrenic nerve conduction latency and height of volunteer. The regression line is shown.*

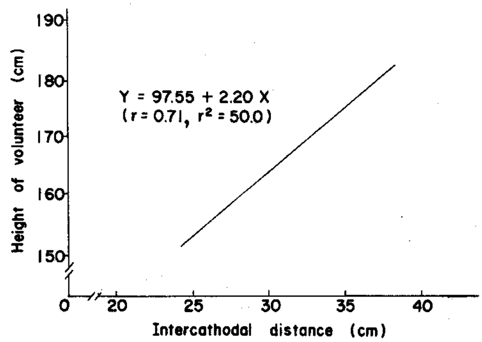

Fig. 2. *The relationship between phrenic nerve intercathodal distance and height of volunteer. The regression line is shown.*

given in Table 1.

Values for conduction latency and intercathodal distance were obtained and statistical analysis of these data was done as calculation of mean values for each side with comparison of the right side vs left side (Table 2, 3). Because there was normally no significant latency difference between the sides of the body, mean values for each parameter were calculated using the pooled data from right and left sides for further study.

Correlation between two parameters (conduction latency and intercathodal distance) as well as these parameters with height was also made (Fig. 1, 2 and 3).

The 95 percent confidence limits for conduction latency and intercathodal distance based on the regression equation were calculated. A significant positive correlation of conduction latency with intercathodal distance was found with a correlation coefficient of + 0.69 and a coefficient of determination of 46.99. The equation of the regression line of Y on X was Y = 19.05 + 1.99 X, where Y was the intercathodal distance (cm) and X was nerve conduction latency (msec) (Fig. 1).

There was also a significant positive correlation between subject height and intercathodal distance ($P>0.05$). The correlation coefficient was + 0.71 with a coefficient of determination of 50. The equation of the regression line of Y on X was Y = 97.55 + 2.20 X, where Y was height of subject (cm) and X was intercathodal distance (cm) (Fig. 2).

DISCUSSION

Since 1783 when Christoph Hufeland proposed the application of electricity to the phrenic nerve in asphyxia of newborn infants, various techniques have been used to stimulate the phrenic nerve (Schechter, 1970). The diaphragmatic action potential was recorded satisfactory by inserting needle electrode into to the edge of the diaphragm (Taylor, 1960) or by mounting surface electrodes on an esophageal tube (Draper *et al.,* 1957; Taylor, 1960). However these techniques are uncomfortable for the subject. It is considered too time consuming to achieve satisfactory relaxation in the subject. In Davis's study the clinical application of the technique was proven to measure phrenic nerve conduction latency with percutaneous stimulation of the nerve and recording with surface electrodes.

Since Glenn reported first in 1964 on electrophrenic respiration by radiofrequency induction diaphragmatic pacing has been developed successfully (Glenn *et al.,* 1964). The benefits of electrophrenic respiration are significant for the patient who requires for chronic ventilatory assistance. When a diagnosis of diaphragmatic paralysis is confirmed, further study should be undertaken to assess the state of phrenic nerve transmission so that consideration can be given to phrenic nerve for pacing.

Knowledge of the normal value of the phrenic nerve conduction latency according to Korean physical characteristics may be helpful when choosing electrophrenic respiration candidates and for evaluating diaphragmatic function postoperatively.

The speed of response of the peripheral motor nerve increased with age upto the fourth decade but decreased thereafter (Norris *et al.,* 1953; LaFratta and Canestrari, 1966). Previous studies were made without this consideration (Davis, 1967; MacLean and Mattioni, 1981). Therefore in this study volunteers were selected for age ranging from the second decade through the fourth decade in order to give the fastest response in nerve conduction.

A positive correlation of intercathodal distance with conduction latency is found, revealing that latency increases with the intercathodal distance. The strength of the relationship is also satisfactory (r^2) between conduction latency and intercathodal distance. It can be seen that the intercathodal distance increases with subject height.

Therefore it is necessary to standardize phrenic nerve conduction values according to physical characteristics as far as height is concerned.

Although the technique of MacLean's study was different from ours, his results may conflict with ours (MacLean and Mattioni, 1981).

The results of a t-test comparing Davis's and our mean phrenic nerve conduction latencies are presented in Table 4. No significant difference is found ($P>0.05$). In comparison with Davis the results of our study in phrenic nerve conduction latency are found to be satisfactory for clinical use.

CONCLUSION

A historical review of the literature is made in electrophysiologic study of the phrenic nerve.

The mean value for conduction latency and intercathodal distance on electrophysiologic study of the phrenic nerve in healthy Korean adult volunteers are 7.1 msec (SD 0.14) and 33.2cm (SD 0.41) respectively. The mean value of their height is 170.2cm (SD 7.66).

There is a positive correlation between these estimates.

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