of normal some years after CBR. However, the hypoxic response was not demonstrated to be 0 immediately postoperatively.

Dr. Winter: While the Japanese surgeons are excellent, I am not aware of publication by them of histologic verification of removal of carotid body tissue following surgery. This unfortunate omission must be clarified to allow physiologic evaluation. In addition, the vast majority of cases performed in Japan were unilateral carotid body resections with few reported bilateral resections. Since loss of ventilatory response to acute hypoxemia requires at least bilateral carotid body resection, the type of surgery performed must be documented to allow proper evaluation.

Dr. Bisgard: In the pony following CBR, PaCO₂ rises 4 mm Hg indicating hypoventilation at rest. Then during exercise, there is regulation at this higher resting value, ie no further hypoventilation.

Respiratory Failure

Airway Occlusion Pressure and Respiratory Nerve and Muscle Activity in Studies of Respiratory Control*

Melvin Lopata, M.D.; Myron J. Evanchik, Ph.D.; Ergün Onal, M.D.; Gabriel Zubillaga, M.D.; and Ray V. Lourenço, M.D.

We have evaluated the relationship between respiratory nerve and muscle electrical activity and airway occlusion pressure in both anesthetized animals and conscious humans. This relationship which reflects the coupling of the neuromuscular components of the respiratory control system was studied under conditions of unloaded and loaded breathing.

In anesthetized cats, changes in phrenic nerve activity, quantified as a moving time average (PNG(t)) were compared to changes in intratracheal pressure (Prr) obtained during complete airway occlusion at functional residual capacity (FRC). Prr plotted against PNG(t) during the course of an inspiratory effort while breathing room air, and at different levels of PaCO₂ during CO₂ rebreathing showed an approximately linear relationship. During the course of CO₂ rebreathing, increases in Prr and PNG(t), both obtained 150 msec after the onset of the occluded breath, were linearly related with high correlation coefficients. Therefore, both during single breaths at different levels of PaCO₂ and during the course of CO₂ rebreathing, inspiratory muscle pressure appears to be linearly related to phrenic nerve activity.

During room air breathing in the intact cat, the relationship between Prr and PNG(t) usually became somewhat linear with positive pressure breathing (PPB), but the overall slope, though slightly diminished, was similar to that at FRC (Fig 1). At low lung volumes induced by negative pressure breathing (NPB), Prr/PNG(t) relationships were not greatly changed from control (Fig 1). With bilateral vagotomy, changes in lung volume had a more pronounced effect on occlusion pressure-phrenic nerve relationships. With PPB, the linear slope of the X–Y plot was markedly decreased from that at FRC (Fig 1), indicating a decrease in inspiratory muscle pressure for a given degree of phrenic drive, while NPB resulted in a slight increase in the slope, demonstrating somewhat an increased efficiency of neuromuscular coupling. These data indicate that vagally-mediated reflexes probably recruit abdominal muscles whose contraction serves to maintain diaphragm configuration and optimal length-tension relationship during PBP, and point out the dependence of occlusion pressure not only on lung volume, but on the activity of other respiratory muscles which support diaphragm function.

In conscious humans, mouth occlusion pressure measured 150 msec after the onset of inspiration (P₀₁₅) was compared to diaphragmatic EMG (EMG₀₁₅) during both CO₂ and hypoxic rebreathing. EMG₀₁₅ was obtained via a bipolar esophageal electrode, amplified and quantified as a moving time average.

During hypercapnia, plots of P₀₁₅ vs EMG₀₁₅ were linear (Fig 2). During hypoxia, although the P₀₁₅ EMG₀₁₅ responses to decreasing PaO₂ were hyperbolic,

*From the Department of Medicine, Pulmonary Section, University of Illinois Abraham Lincoln School of Medicine and VA Hospital West Side, Chicago.

Supported by National Institutes of Health Grant HL-14735.

Reprint requests: Dr. Lopata, University of Illinois Medical Center, Pulmonary, Rm. 819, 900 South Hermitage, Chicago 60612.

CHEST, 73: 2, FEBRUARY, 1978 SUPPLEMENT

NEUROMUSCULAR AND CHEMICAL CONTROL OF BREATHING 285

Figure 1. Plots of intratracheal pressure vs phrenic nerve activity (PNGμV) in the intact (left column) and vagotomized (right column) cat. The middle tracings were obtained at atmospheric pressure (0 cm H₂O) (note linear Prr/PNG(t) relationship) and the upper and lower tracings were obtained during positive (+15 cm H₂O) and negative pressure (−15 cm H₂O) breathing, respectively. See text for details.
plots of $P_{0.15}$ vs $EMG_{DI}$ were linear (Fig 2). In subjects with normal lung mechanics, changes in $P_{0.15}$, therefore, can be considered to reflect changes in inspiratory muscle drive.

The effects of inspiratory flow resistive loading on $P_{0.15}$ $EMG_{DI}$ relationships were studied in normal subjects by comparing unloaded and loaded responses to hypercapnia during the same sitting. Two degrees of flow resistance were studied, 5 and 14 cmH$_2$O/L/sec. The slope of $P_{0.15}$ vs $EMG_{DI}$ was significantly increased from control in one-half of the subjects with the lesser load, and in two-thirds of the runs with the greater load, demonstrating that occlusion pressure increased for a given degree of diaphragmatic activity.

This increase in inspiratory muscle pressure per diaphragmatic activity occurring with loading in some subjects can be due either to the recruitment of other inspiratory muscles, such as external intercostals, or to the increased efficiency of inspiratory muscle contraction due to intrinsic muscle mechanisms.

We propose that the latter mechanism is the operative one, that other respiratory muscles including the intercostals and abdominals may play a pivotal role in defending, or even increasing, diaphragm efficiency by maintaining an abdominal position that results in a diaphragmatic configuration which provides optimal force generation or neuromuscular couplings.*

Because this concept implies that measures of occlusion pressure may not necessarily be considered a true index of inspiratory motoneuron drive under conditions of altered mechanics, we propose that in studies of respiratory control occlusion pressure be regarded as an index of total neuromuscular output of the respiratory system, implying its dependence not only on neural input, but on factors that determine muscle output.

We also propose that the quantitative measure of respiratory nerve and muscle activity along with occlusion pressure and ventilation may provide a means of assessing the neuromuscular-mechanical components of the respiratory control system, in the normal state, under loaded conditions, and in disease.

**REFERENCES**


**DISCUSSION**

Comment: We found increased phrenic nerve activity with airway occlusion. In CPPB, however, there was decreased phrenic discharge. Therefore, our airway occlusion techniques may not be appropriate when CPPB is used.

Dr. Lopata: We did not study this. It should be pointed out that other inspiratory muscles are likely to protect the diaphragm by placing it in a more favorable mechanical position.

**The Perception of Changes in Airflow Resistance in Normal Subjects and Patients with Chronic Airways Obstruction**

Stewart B. Gottfried, M.D.; Murray D. Altose, M.D.; Steven G. Kelsen, M.D.; Charles M. Fogarty, M.D.; and Neil S. Cherniack, M.D.

During acute changes in mechanical properties of the ventilatory apparatus, compensatory mechanisms are brought into play which restore ventilation toward control levels. The new level of ventilation depends upon the intrinsic properties of the respiratory muscles and...