Symposium on Dyspnea

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(1) Some Considerations on Mechanisms of Dyspnea

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Many theories have been offered to the mechanism of dyspnea:

(a) Hypoxemia (Wasserman, et al., 1961), (b) Hypercapnia (Patterson, et al., 1962),
(c) Acidosis (Gesell, 1925), (d) Excessive work of breathing (McIlroy, 1959), (e) Excessive oxygen cost of breathing (Cournand, et al., 1954), (f) Variations in intrapleural pressure (Marshall, et al., 1954), (g) Pulmonary vascular engorgement (Mauck, et al., 1961), (h) Decreased respiratory center inhibition by stretch receptors (Wright & Branscomb, 1954), (i) Length-tension inappropriateness (Campbell & Howell, 1962) and (j) Increased sensitivity of respiratory center.

Several of the important theories are discussed below using data including ours.

1) Biochemical Changes of the Blood

Decreased arterial Po2, raised Pco2 or lowered pH is often associated with the dyspneic patients, yet dyspnea may occur when blood gases are within normal limits. Our results showed that the fall of Pao2 in patients of Fallot's tetralogy is linearly related to the degree of dyspnea. On the other hand, in cases of chronic pulmonary emphysema the degree of dyspnea is not related to Pao2 nor Paco2. Nevertheless, as were reported by Patterson and Wasserman, there must be some cases in which these humoral changes would become a determinant of dyspnea.

2) The Work of Breathing

The relationship of dyspnea to the work of respiratory muscles was investigated by Christie (1953). A hypothesis which may fits most of the patients of cardiopulmonary disorders is that dyspnea is experienced when the work of breathing is excessive (McIlroy, 1959).

McIlroy compares the dyspnea with angina and suggests that the factor initiating

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the embarrassment of the muscles is the relative lack of oxygen when their work is excessive. Our results showed the flow resistive work is related to the degree of dyspnea in patients of chronic obstructive lung diseases, although one healthy subject does not complain of any dyspnea even when the total respiratory work exceeds 7 Kg.m./min. There are many exceptions which cannot be explained by this theory. As Mcllroy himself points out, dyspnea can occur in patients when the work of respiratory muscle is not increased, or even patients in whom there is no muscle work at all (as complete paralysis of respiratory muscles by poliomyelitis).

The measurement of oxygen cost of breathing (Cournand et al., 1954) is another way to estimate the work of breathing. This measurement was also carried out on normal subjects, patients of pulmonary emphysema and those of pulmonary fibrosis, and some correlations were obtained with the degree of dyspnea.

3) Decreased Respiratory Center Inhibition by Stretch Receptors

This concept is that dyspnea is due to an unusually prolonged and intense discharge of the neurons in the inspiratory center, which is normally interrupted by proper vagal inhibitory impulses from stretch receptors in the lungs.

There revealed some weakness in this theory, by the vagal block experiment of Widdcombe (1961) and Guz (1964) who have shown that the Hering-Breuer reflex in adult man is almost ineffective.

4) Length-Tension Inappropriateness

Campbell & Howell (1962) have used the term “length-tension inappropriateness” to describe the sensation of breathlessness. They believe that dyspnea may arise from an unbalance between the demand of the respiratory centers for ventilation and the actual ventilation performed. Although not tested in man, this concept is, we think, the most satisfying concept.

We tried to determine if this theory may play a determinant role in the development of dyspnea in health and disease. As the information of “tension”, we used the action potential of the diaphragm and the oxygen cost of the respiratory muscles. “Length” information was obtained from ventilation volume. Hyperventilations were performed by increasing the respiratory dead space as far as possible until the subjects gave up because of dyspnea.

The data, collected in normal subjects and the patients of pulmonary emphysema and those of pulmonary fibrosis, show that the sensation of dyspnea is fairly well related to the ratio \( \dot{V}_o / V_e \) (tension-length). If this ratio exceeds 4 ml./L., almost every subject complains of dyspnea.

5) Increased Sensitivity of Respiratory Center

Increased ventilatory response to the stimuli must have something to do in the development of dyspnea. If the respiratory center sends excessive motor output in response to any ventilatory stimuli, work of breathing may increase excessively, or the length-tension inappropriateness may occur.

Here, I will show interesting case of chronic pulmonary emphysema. At the time of admission, this male patient of 67 years had severe hypoxemia with hypercapnia.
and respiratory acidosis (Pao2 45 mm.Hg, Paco2 57 mm.Hg, pH 7.34). After several months of intensive therapy, his subjective complaint of dyspnea was rather increased although the blood gas showed remarkable improvement (Pao2 72 mm.Hg, Paco2 41 mm. Hg, pH 7.39). O2 cost of breathing of this patient measured by CO2 loading revealed remarkable increase (from 0.45 ml. of O2/mm.Hg of PEO2 to 3.0 ml. of O2/mm.Hg of PEO2) by the therapy, although the VE response to CO2 was not increased. If true response of respiratory center to CO2 is obtained by the measure of O2 cost of respiratory muscle (Fritt et al., 1959), the paradoxical complaint of dyspnea in this patient could be explained as results of the improvement of the respiratory center.

6) Ventilatory Response of Carbon Dioxide

It has been known for many years that patients with diffuse obstructive lung disease have a reduced ventilatory responsiveness to carbon dioxide. For this two explanations have been offered.

a) The reduction is simply the effect of mechanical impedance, and the motor output of respiratory center is normal to elevation of PCO2.

b) There is true reduction in the responsiveness of the whole respiratory apparatus to CO2, and the motor output of the respiratory center is reduced to the elevation of PCO2.

Most papers published seem to be in favour of the first explanation.

Work of breathing or the oxygen cost of breathing previously mentioned will be a good measure to detect the true response of respiratory center. The measurement of the tension of the respiratory muscles seems to be a better way to know the activity of the respiratory center or its motor output. For this reason, the action potentials of the diaphragm were derived through an esophageal bipolar lead. The action potentials were integrated electrically and calculated quantitatively. As the results, two types were found in the patients of reduced ventilatory response, and these findings are similar to those obtained by Howell (1965) using work method.

In conclusion, it might be difficult to explain all types of dyspnea using one theory, unless we could discover the location of true receptors, pathways and centers for the perception of the dyspnea.