A RESPIRATORY REFLEX ORIGINATING FROM THE THORACIC WALL OF THE DOG *

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Prior to the middle of the nineteenth century, reflex stimulation of the respiration by fumigation of the rectum, friction, and so forth, was the chief measure relied upon for resuscitation. Since the development by Marshall Hall in 1857 of a manual method for producing an artificial respiration, reflex stimulation of the respiration has assumed secondary importance (2, 3, 4). Tongue traction (5), anal stretching, and other methods, however, are still frequently employed, although little is known about their effectiveness. We were afforded an opportunity to investigate respiratory reflexes during the course of a series of controlled resuscitations from measured overdoses of pentothal sodium carried out in continuation of similar experiments with ether, divinyl ether, and chloroform (6, 7). Our experiments have revealed the existence of a respiratory reflex which is more effective in anesthetic depression than is either tongue traction or anal stretching. It is initiated by the application of light pressure to a localized area of the chest wall. The results of investigations into the nature of this reflex are presented.

PROCEDURE

Three groups of experiments have been carried out. In the first series, which consisted of 60 experiments on intact dogs, a 2.5 per cent solution of pentothal sodium was injected intravenously by means of a mechanical injector until respiratory arrest occurred. A mouth hook delivering 10 liters of oxygen per minute was placed in the dog's mouth and the state of respiratory arrest maintained by continuous injection of the anesthetic. A brief period of artificial respiration was then given in order to replace the nitrogen within the respiratory tract by oxygen. In the dog so prepared, sufficient oxygen for its metabolic needs continues to enter the respiratory tract from the oxygen-enriched atmosphere maintained at the glottis, even though the animal is in complete respiratory arrest. Under these experimental conditions, the animal

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† A preliminary report of this work has been published (1).
may live for periods up to an hour and a quarter without breathing. Draper and Whitehead (8) have termed this phenomenon "diffusion" respiration. Diffusion respiration comes into play when the following conditions are present: (a) adequate circulation, (b) patent airway and (c) replacement of the nitrogen in the respiratory tract and in the atmosphere at the region of the glottis by oxygen. This type of respiration is distinguished sharply from artificial respiration by the fact that no external force of any kind is employed. The reader is referred to

**Fig. 1.** Dog, male, wt. 14.8 Kg. Respiratory arrest maintained by continuous injection of a 2.5 per cent solution of pentothal sodium. Spriometer filled with oxygen and filled with soda lime chamber. Time intervals six seconds. The distance between each horizontal row of dots represents 35.1 cc. of oxygen at 760 mm. Hg. B.P. and 23 C. Anal reflex elicited by stretching the anus. Color of tongue good throughout experiment. The progressive rise of the base line is owing to the fact that in diffusion respiration, oxygen continues to leave the spirometer bell and to enter the respiratory tract of the animal throughout the intervals between respirations.

figures 1 and 2 for examples of the continued uptake of oxygen (as indicated by the upward slant of the base line) during periods of respiratory arrest.

In a second series of experiments, in which 23 dogs were used, the character of the respiratory response was studied by attaching a sensitive and balanced recording spirometer filled with oxygen and provided with a soda lime absorber to a cannula tied in the trachea. Anesthesia was produced and respiratory arrest was maintained as described
above. Diffusion respiration provided adequate oxygenation during the periods of respiratory arrest. Using this technic it is possible to secure quantitative data on the volume of gas moved with each respiration and on the time relationships between inspiration and expiration.

Fig. 2. Dog, male; wt. 13.8 Kg. Respiratory arrest maintained by continuous injection of a 2.5 per cent solution of pentothal sodium. Rectus abdominis muscle and tendon, scalenus medius muscle and tendon laid bare but not dissected clear, leaving the circulation and nerve supply intact. Sphragemeter filled with oxygen and fitted with soda lime chamber. Time intervals six seconds. The distance between each horizontal row of data represents 23.1 cc. of oxygen at 760 mm. Hg. B.P. and 23 C. Color of tongue good throughout experiment except for short intervals of slight cyanosis. Muscle stimulation by very light touch of finger upon external surface of muscle or tendon concerned.

Code: Rectus abdominis muscle = R.M.
Rectus abdominis tendon = R.T.
Scalenus medius muscle = M.S.M.
Scalenus medius tendon = M.S.T.
In a third series of 9 experiments on dogs we attempted, by means of anatomical dissection and stimulation of individual structures, to determine which of the tissues of the thoracic wall contained the end organs concerned in the reflex. A recording spirometer was attached to the animal’s trachea and diffusion respiration was employed.

Experimental Results

1. Experiments on Intact Dogs.—With the animals in respiratory arrest but in a state of good oxygenation, the presence of a reflexogenous zone localized in the region of the maximal cardiac impulse on the left chest wall and in the corresponding area on the right chest wall can be demonstrated. When this area is lightly palpated, a reflex respiratory response occurs which is characteristically powerful and certain, provided the animal is not too profoundly depressed by the anesthetic. Under favorable conditions, the reflex may be elicited repeatedly.

2. Experiments in Which the Character of the Respiratory Response Was Studied by Means of a Recording Spirometer.—Figure 1 is representative of this group of experiments. The thoracic wall reflex is shown to be capable of eliciting respiratory responses at a level of anesthetic depression at which tongue traction and anal stretching are not effective. When a somewhat lighter degree of anesthesia is employed but with the animal still in respiratory arrest, a reflex respiratory response to tongue traction and anal stretching can often be obtained but with less certainty than from the sensitive area of the thoracic wall.

The thoracic wall reflex has the following characteristics: The adequate stimulus is light pressure. The respiratory act induced is carried out in a smooth and normal manner and is largely diaphragmatic; inspiration is accompanied by abduction of the vocal cords. There is practically no delay between inspiration and expiration. Fatigue of the reflex may occur but its sensitivity is rapidly restored. The respiratory response characteristically moves a substantial volume of gas. For example, in the experiment shown in figure 1, the amount of gas moved with each respiratory act varied only slightly and averaged 218 cc. The reflex is susceptible to inhibition and may disappear in severe hypoxia or shock. In extremely deep levels of anesthetic depression the reflex is not obtained, but on allowing the anesthesia to lighten, it reappears at a variable period before the resumption of spontaneous respiration. In one experiment it was obtained thirty-five minutes before the resumption of spontaneous breathing. Compared with anal stretching and tongue traction, the thoracic wall reflex was, in our experience, the last to disappear as the anesthesia deepened and the first to reappear as the anesthesia lightened. In addition to its presence under pentothal sodium, we have demonstrated the reflex in the dog in respiratory arrest produced by chloroform and in the dog and rabbit depressed by pentobarbital sodium.
3. Localization of the Reflexogenous Zone Through Anatomical Dissections.—We were unable to elicit the reflex from the skin, subcutaneous tissue, periosteum of the ribs or the intercostal muscles. In the dissected subject, however, the reflex was obtained following very light pressure applied to the distal end of the scalenus medius muscle and its tendon or to the proximal end of the rectus abdominis muscle and its tendon. A series of reflex responses from these tissues is shown in figure 2.

The anatomical relationships of these sensitive tissues are shown in figure 3. In the dog the scalenus medius muscle proceeds down the side of the chest to be inserted into the eighth and ninth ribs (9). Its broad aponeurosis curves medially and blends with the aponeurotic tendon of the rectus abdominis. The reflex is obtained most certainly from an area approximately an inch and a half in diameter surrounding the point marked "A" in the diagram. Included in this area are the terminal fibers of the scalenus medius and rectus abdominis muscles and their aponeurotic tendons. Dissection of these muscles and tendons from the underlying structures or trauma to them abolishes the reflex. Unpublished work in this laboratory by D. D. Plumb suggests that the afferent nerves of the reflex arising from the scalenus medius enter the cervical cord and those arising from the rectus abdominis enter the thoracic cord.

Comment

Although it has been known for some time that widespread and deforming pressure on the thorax will induce marked stimulation of respiration (10), detailed information concerning the reflex mechanisms concerned is lacking. From the results of the studies of Gesell and
Moyer (11), it appears likely that at least a part of the respiratory response to pressure on the thorax comes from reflexes arising in the thoracic wall. These investigators found that the respiratory rate is augmented when sustained positive pressure is applied to the torso under conditions which avoid pulmonary deformation. Apparently, however, a widespread stimulation was used and their animals were not in respiratory arrest.

The experimental results reported in the present paper show that a reflex respiratory response may be obtained from the application of light pressure to a circumscribed area of the chest wall. That the pressure used did not deform the lungs is shown by the fact that, although the spirometer was sensitive to 2 cc. of gas, the pressure exerted on the superficial thoracic structures during elicitation of the reflex was not sufficient to expel a measurable amount of gas from the thorax (figure 1).

It may be significant that the reflex arises with apparently equal power from two muscles and their tendons which have opposite respiratory functions, i.e., accessory inspiratory and accessory expiratory, and which, at least in the dog, happen to be in close anatomical relationships. Gesell and co-workers in numerous papers (reviewed by Gesell and Hamilton (12)) have presented evidence for the existence of two half-respiratory centers which respectively preside over inspiration and expiration. According to their concept certain afferents affect both centers more or less equally; others exert their influence predominantly upon one or the other. The afferents from cutaneous sensory nerve endings, called by them nocireceptors, provide a general respiratory drive distributed to both half centers which results in an increase in even proportions of both the inspiratory and expiratory phases of respiration. It appears possible that a similar situation obtains with respect to the afferents from the deep pressure receptors responsible for the thoracic wall reflex because we have always obtained a notably rhythmic response, which in the presence of spontaneous respiration, takes the form of a marked augmentation of the rate. At no time have we observed a stimulation which affected predominantly either phase of the respiratory cycle.

On numerous occasions we have employed the reflex as a substitute for artificial respiration following overdoses of pentothal sodium and pentobarbital sodium. It has been effective when the depression was not too deep. In one instance a dog which was in respiratory arrest following an overdose of pentobarbital sodium intraperitoneally, was kept breathing for one hour and fifteen minutes and, in the end, was successfully resuscitated by means of this reflex alone. Students in our pharmacology class have become familiar with the value of this reflex as an aid to resuscitation and have successfully used it for this purpose on many occasions.

The existence of this reflex in the human is undemonstrated but, if
A Respiratory Reflex present, should prove a valuable aid to resuscitation. For the guidance of those who may be interested in searching for the reflex in the human, we call attention to the following: (1) We have been able to elicit the reflex only in anesthetized animals and (2) the anatomical relationships of the scalenus medius and the rectus abdominis muscles in the human are very different from those of the dog and other four-footed animals.

SUMMARY

1. A respiratory reflex present in the dog and active in deep levels of anesthetic depression has been described.
2. It originates from the left chest wall in the region of the maximal cardiac impulse and from the corresponding area of the right chest wall. It is set in motion by light pressure.
3. The sensitive structures concerned include the proximal end of the rectus abdominis muscle and its tendon, and the distal end of the scalenus medius muscle and its tendon.
4. The reflex is capable of resuscitating dogs in respiratory arrest from overdosage with pentothal sodium or pentobarbital sodium.
5. The reflex is a more active stimulus to respiration than is either tongue traction (Labordé) or anal stretching.
6. A description of the characteristics of the reflex is given.

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REFERENCES