Measurement of dynamic resistance to breathing in unanesthetized dogs

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McILREATH, FRED J., JR., ALBERT B. CRAIG, JR., AND ANTHONY J. ANZALONE. *Measurement of dynamic resistance to breathing in unanesthetized dogs* J. Appl. Physiol. 16(3): 463–464. 1961. Measurements of air-flow resistance were made using unanesthetized dogs prepared with exteriorized tracheas. Pressure-flow relationships obtained from these experiments adhered to Rohrer's equation. Drugs that are classically known to alter tone of bronchial musculature substantially change the pressure-flow relationship in these animals.

RESPIRATORY MEASUREMENTS in unanesthetized animals have been difficult and have yielded minimal information. Recently, Agostoni et al. (1) studied the dynamic resistance of breathing in various species of anesthetized animals. This technique, modified and applied to unanesthetized dogs, has served as an indication on bronchial tone, i.e. degree of bronchoconstriction before and after administration of certain drugs.

METHODS

Dogs were anesthetized with sodium pentobarbital (30–40 mg/kg, iv). A transverse incision was made across the midventral aspect of the neck. From this point, two skin flaps (2.5 × 10 cm) were made extending cephalically and caudally. The trachea was exposed and a section approximately 1 cm^2 was removed (Fig. 1*A*). The ends of the flaps were stitched to the opening in the trachea, and the side incisions sutured so as to create two new flaps covering the opening in the trachea (Fig. 1*B*). The animals were allowed to convalesce for 2 weeks before being used in an experiment. All operating procedures were carried out under aseptic conditions.

At the time of the experiment an endotracheal tube, with cuff, was coated with Nupercainal ointment and inserted into the opening in the trachea. The cuff was inflated with water to completely block the passage of air through the upper trachea. The effectiveness of the cuff was verified by holding a mirror to the dog's nostrils; any air escaping caused the mirror to fog. A Statham strain-gauge pressure transducer was connected to a side tube between the endotracheal tube and an air-flow interrupter. To the opposite side of the interrupter was connected a flowmeter which consisted of a monel screen. The differential pressure across this resistance was measured with another Statham strain gauge. Outputs of both strain gauges were recorded simultaneously on a Sanborn Twin-Viso recorder. Standard pressure-flow curves of the dogs were determined by interrupting air flow at numerous points on the respiratory cycle. Resistance of the system itself was determined and found to be linear with flow and not significant when compared to air-flow resistance. For simplicity it was not considered in the calculations.

Drugs were administered in amounts indicated either intravenously or as an aerosol.

RESULTS

Fig. 2 shows the pressure-flow curve obtained from three animals. These curves represent between six and eight measurements obtained over a period of several months. The animals had first been allowed to become accustomed to the procedure and were not emotionally disturbed by the experiment.

The curves from the three dogs are almost identical, and all adhere to Rohrer's formula: $P = k_1V + k_2V^2$. By plotting the mean data as P/V versus V, k_1 becomes the intercept and k_2 the slope. The k values are shown in Table 1, and are in good agreement with those reported by Agostoni et al. (1).

Intravenous injection of 1.5 mg/kg of ephedrine sulfate caused a substantial decrease in resistance to air flow within 15 min (Fig. 2). The effect persisted for slightly less than 1 hour. Histamine given intravenously had no effects on the resistance, while aerosols of this drug produced only erratic responses. Carbamylcholine in the form of a 20% aerosol did produce a consistent increase in the resistance (Fig. 2). The time necessary for the re-

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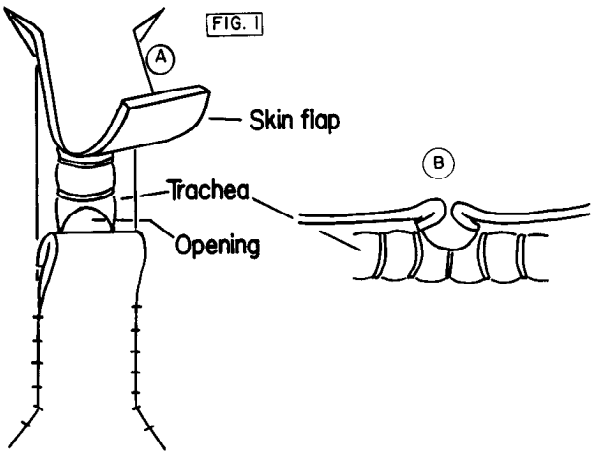

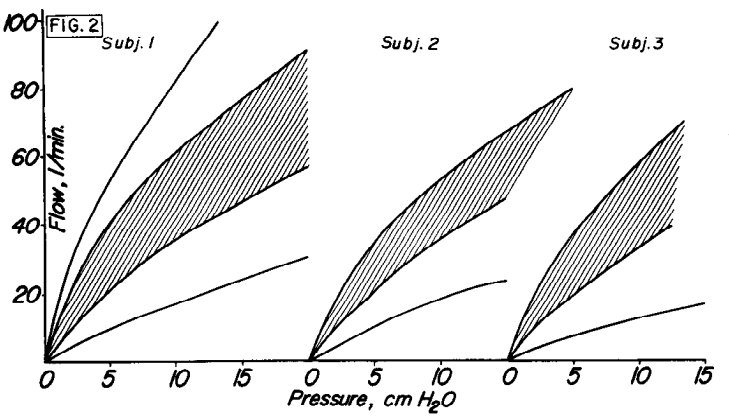

FIG. 1. Semidiagrammatic illustration of exteriorized trachea and skin flaps. Note that a small skin wedge has been removed from attached ends of flap to compensate for difference in length created by folding free end of flap.

FIG. 2. Pressure-flow relationships in 3 dogs. *Shaded areas* represent curves obtained from 6–8 experiments on each animal. *Upper curve* of *dog 1* is that obtained after iv injection of 1.5 mg/kg of ephedrine sulfate. *Lower curves* of each dog were obtained following administration of 20 % carbamylcholine aerosol.

sponse to become apparent varied somewhat, but generally was less than 3 min. Quite often the animals became prostrate but recovered rapidly when the aerosol was discontinued. Urination was common, as was brief retching. Although resistance to flow markedly increased, the animals were able to reach flow rates that allowed them enough air exchange to prevent cyanosis.

DISCUSSION

The skin flaps formed over the opening of the trachea are of major advantage in maintaining these animals in good health over a long period of time. Without the flaps, animals developed a chronic cough with the production of copious amounts of drainage from and around the trachea. In those animals with flaps, normal respiration was through the upper airway. They healed quickly and showed no signs of irritation or chronic infection.

TABLE I

Dog	No. of Exp.	cm H_2O/liter/min		cm $H_2O/l^2/min^2$	
		k_1	Range	k_2	Range
1	8	0.08	0.045–0.16	0.0025	0.0010–0.0034
2	6	0.12	0.07–0.225	0.0023	0.0019–0.0024
3	8	0.12	0.07–0.21	0.0024	0.0021–0.0025

The justification for and the limitations of using pressure flow as an indication of respiratory resistance has been discussed at some length (2, 3). As indicated, care must be taken in keeping the external dead space very small in relation to total alveolar volume so that on interruption of air flow very rapid equalization of pressure occurs. In the present studies the dead space was less than 20 ml. According to the measurement of alveolar volume in dogs by Agostoni et al. (1) this added space was less than 2 % of the total volume.

In his theoretical analysis of respiratory resistance, Rohrer concluded that changes in the cross-section area of the respiratory tract are a major factor of the degree of resistance during normal breathing. The results of our experiments amply substantiate this conclusion. Drugs that are classically known to affect the tone of bronchial musculature produce substantial changes in pressure-flow relationship.

It was noted that there was considerable variation in the pressure-flow relationships from day to day. Such deviations are probably due to physiological changes in bronchial tone rather than to errors in measurement.

Neergaard and Wirz (4) reported that expiratory resistance was greater than inspiratory resistance in patients with bronchial asthma. Theoretically this is what one would expect, but in the data obtained from the dogs whose bronchioles were constricted with either histamine or carbamylcholine, we found no evidence that expiratory resistance was different from inspiratory resistance.

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