ROLE OF VAGUS IN THERMAL PANTING

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Summary: In dogs anaesthetised with pentobarbitone sodium, raising the body temperature from 37°C to 42°C increased the rate of respiration and pulmonary ventilation but decreased the tidal volume. A similar change though of a lower magnitude, was observed in these parameters after cold blocking the vagi. At 40°C body temperature, however, the vagal block was not effective in reducing the rate. The significance of hyperthermic panting mechanism dominating the Hering-Breuer mechanism at 40°C has been discussed. It has been postulated that the vagi carry temperature dependent afferents that have effect opposite to the Hering-Breuer reflex. At 42°C when respiratory failure usually sets in the temperature regulating function of respiration is the last to be lost.

Key words : Hering-Breuer reflex thermal polypnoea panting temperature regulation

INTRODUCTION

The vagi through the Hering-Breuer reflex maintain an accelerated rhythm and a low depth of respiration by cutting short the depth of inspiration. Thermal polyponea also results in similar changes in respiration (6). The present investigation was undertaken to study the relative significance of these two mechanisms under hyperthermic state of the body.

MATERIALS AND METHODS

The present study was conducted in a set of 20 healthy mongrel dogs of either sex weighing between 10 to 20 *kg*. They were anaesthetised with sodium pentobarbital (30 *mg/kg*) given intraperitoneally. The respiration rate was recorded on the kymograph by introducing and inflating a large toy balloon inside the oesophagus. Pulmonary ventilation was measured by a Siebe Gorman gas-meter which was connected to the trachea through an air tight two-way tube. The whole system had a low airway resistance. By a prior test it was found earlier that it could faithfully record small samples of air blown through it. The gas-meter and an electromagnet were so incorporated in an electric circuit that every 1.25 litres of ventilation was recorded on the kymograph. The tidal volume was calculated from the number of respirations between two 1.25 litre marks; and pulmonary ventilation was calculated by multiplying tidal volume with respiration rate. Deep rectal temperature was recorded by a thermometer. The temperature of the animal was brought to 37°C by cooling or warming the animal as the case required; and was then raised by applying radiant heat from two 40 watt carbon bulbs and by raising the temperature of the animal plate. The vagi were cold-blocked at 0 to 4°C by placing them on a groove in a copper rod projecting from the base of a receptacle containing a mixture of ice and common salt (7). The nerve was cooled for at least five minutes on the copper rod and record of the last minute alone was taken into consideration.

Mean values for respiration rate, minute ventilation and tidal volume were calculated when vagi were intact and when they were cold-blocked. From the difference between without block state and vagal block state 95% confidence interval was calculated separately for respiration rate, minute ventilation and tidal volume.

RESULTS

The results are tabulated in Tables I and II.

TABLE I

Body temperature			37°C	38°C	39°C	40°C	41°C	42°C
Number of Dogs			18	20	20	14	11	8
Respiration Rate	A	Mean	20.44	31.10	35.00	58.14	121.09	95.75
		SD	5.11	10.49	11.99	15.22	19.85	36.90
	B	Mean	19.78	29.10	31.50	82.43	118.00	92.50
		SD	5.48	11.02	16.27	13.57	17.11	31.05
	A-B	Mean	+0.67	+2.0	+3.5	—24.29**	+3.09	+3.25
		SD	0.158	2.534	2.087	5.148	5.633	6.082
	CI		—2.14	—3.30	—0.86	—35.41	—9.47	—11.10
			+3.48	+7.30	+7.86	—13.17	+15.65	+17.60
Minute Ventilation	A	Mean	3.16	4.57	5.27	7.29	13.63	8.36
		SD	0.80	1.00	1.00	1.31	1.90	1.25
	B	Mean	3.17	4.23	4.42	9.06	12.04	5.05
		SD	0.77	1.46	1.45	1.01	1.73	1.66
	A-B	Mean	—0.01	+0.34	+0.85**	—1.77**	+1.59	+3.31**
		SE	0.216	0.298	0.261	0.474	0.809	0.533
	CI		—0.47	—0.28	+0.30	—2.79	—0.21	+2.06
			+0.44	+2.97	+1.40	—0.75	+3.39	+4.57
Tidal Volume	A	Mean	144.11	153.60	158.55	131.93	115.09	91.25
		SD	20.56	27.04	28.99	25.67	18.25	20.31
	B	Mean	145.75	149.05	158.04	111.71	103.18	51.25
		SD	26.42	27.92	30.38	14.82	13.47	8.34
	A-B	Mean	—1.64	+4.55	+0.15	+20.22**	+11.91	+40.00**
		SE	7.318	6.848	5.325	6.911	6.634	6.814
	CI		—17.08	—9.76	—10.98	+ 5.29	—2.88	+23.92
			+13.80	+18.86	+11.28	+35.15	+26.70	+56.08

** Significantly different from zero at 1% level of significance.

A—Without vagal block
B—With vagal block
CI—95% Confidence interval
SD—Standard deviation
SE—Standard error

TABLE II: Percentage changes in respiratory rate, minute ventilation and tidal volume at rising body temperatures.

	Vagi not blocked			*Vagi blocked*		
Rectal temp.	*Respiratory rate*	*Tidal volume*	*Minute ventilation*	*Respiratory rate*	*Tidal volume*	*Minute ventilation*
38°C	+ 69	+ 4	+ 75	+ 39	+ 8	+ 50
39°C	+ 70	+ 4	+ 78	+ 57	+ 6	+ 67
40°C	+210	—12	+175	+333	—12	+280
41°C	+579	—14	+492	+486	—17	+380
42°C	+384	—26	+300	+300	—65	+ 40

DISCUSSION

In this study initial resting respiration rate of dogs at 37°C body temperature varied widely between 12 to 30/min (mean 20.44). This compared very favourably with figures of 10 to 30 given by Dukes (2). The increase in respiration rate with the rise in body temperature, which was very well marked above 40°C (Table I) was because dogs, who do not have effective sweat glands lose heat under hyperthermic conditions by panting. A similar sudden increase in respiration between 40 and 41°C body temperature had been reported earlier (5). This increase in rate was found to be significant ($P<0.01$) at each degree rise in body temperature. On cold blocking the vagi at a body temperature of 37°C the respiration rate varied between 14 to 30 with a mean rate of 19.78 (Table I). It has been observed (4 and 7) that the fibres for Hering Breuer reflex travelling in the vagi were blocked at 8°C. Vagal block at 0 to 4°C in the present study therefore resulted in an insignificant decrease in respiration rate. On comparing the respiration rate after cold blocking the vagi at rising body temperatures with similar observations without vagal block it was interesting to observe that, except at 40°C body temperature the percentage increase in respiration rate was lower at all temperatures (Table II). This was because fibres of Hering Breuer reflex were possibly blocked. However, at 40°C body temperature percentage increase in respiration rate on blocking the vagi was much more (333%) than the increase (210%) when the vagi were not blocked. What could this be due to? It is likely that at 40°C body temperature the importance of losing heat was so great that the hyperthermic panting mechanism dominated over the Hering Breuer reflex. At body temperature other than 40°C the Hering Breuer reflex was not supressed. The fact that the temperature of about 40°C is important in dogs was shown earlier by Kumar and Sinha (6), who observed that at about 40.5°C body temperature there operate two further mechanism that help in the regulation of body temperature in dogs. These mechanisms consist of a further increase in respiration rate and an increase in salivary secretion both triggered by opening the mouth. Why was the dominance of panting lost over that of Hering Breuer reflex beyond a body temperature of 41°C is difficult to explain.

On comparing the increase in minute ventilation at each next degree rise in body temperature above 37°C with that at the preceeding, it was always found to be statistically markedly significant ($P<0.001$). The tidal volume increased insignificantly by 4% at both 38 and 39°C.

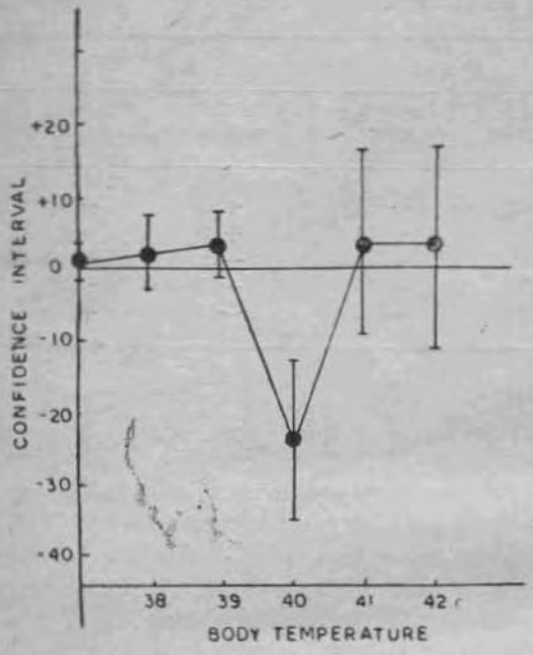

Fig 1: Showing the mean difference of respiration rate before and after vagal block with its confidence-interval.

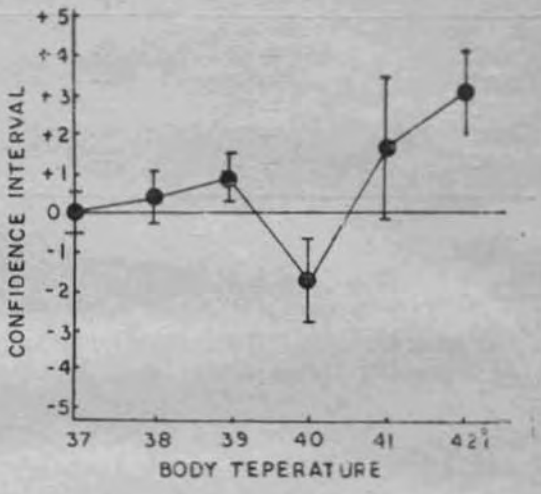

Fig 2: Showing the mean difference of minute ventilation before and after vagal block with its confidence-interval.

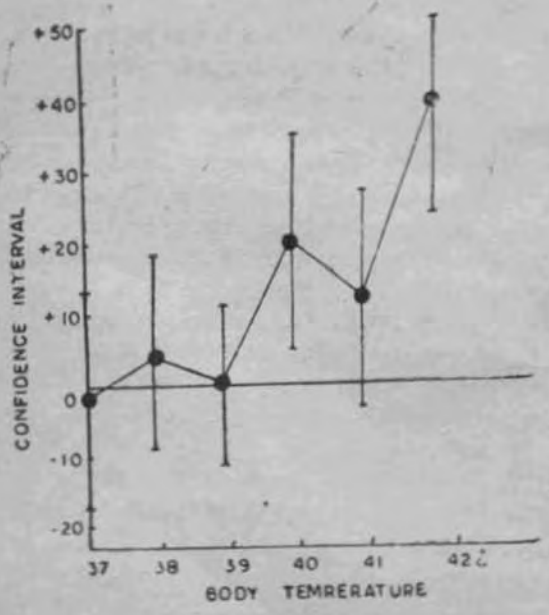

Fig. 3: Showing the mean difference of tidal volume before and after vagal block with its confidence-interval.

but then significantly decreased ($P<0.01$) at 40, 41 and 42°C body temperature (Table II). The decrease in tidal volume at these temperatures was because of tremendous increase in respiration rate resulting in shallow and rapid breathing. The tidal volume decreased to 91.25 *ml* at 42°C body temperature, from a resting value of 144.11 *ml* at 37°C. The ventilation under hyperthermic condition was thus more of dead space than of alveolar air.

When the vagi were cold-blocked the minute ventilation increased upto a temperature of 41°C, but at 42°C it decreased (Table I). This decrease together with resultant mean tidal volume of 51.25 ± 8.34 *ml* (Table I) was very suggestive of respiratory failure. Respiration in dogs serves at least two important functions, viz. gaseous exchange and temperature regulation. Out of these two functions it appeared that at 42°C body temperature the temperature regulating function was the last to be lost. The tidal volume after vagal block showed a slight increase of 8% and 6% at 38 and 39°C body temperatures but beyond 40°C it consistently decreased. This consistent, decrease in tidal volume with a high frequency of respiration rate resulted in better and more efficient heat loss.

The significance of the 40°C body temperature was brought out when 95% confidence interval (CI) was calculated (Table I) and plotted for respiration rate, minute ventilation and tidal volume (Figs. 1, 2 and 3). The fact that the CI for all the three parameters was not cutting the zero line at 40°C body temperature was significant. This was strongly suggestive of some different type of vagal afferents that have an action opposite to that of Hering Breuer fibres. These afferents work optimally at 40°C. Stray observations of increase in respiration rate on blocking the vagi by other workers (1) as also in the present study at temperatures other than 40°C may be because of this.

Hering Breuer reflex makes the respiration rapid and shallow. This accelerated rhythm of respiration is out of proportion to physiological respiratory needs of the body (3). It was therefore suggested (6) that since both thermal polyponea and Hering Breuer reflex make the respiration rapid and shallow, the function of the later is also in temperature regulation.

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