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NOTE

1. This research was supported in part by NIMH Grant MH-14108-01.

The effects of vagotomy on the water intake of the white rat*

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Unilateral, cervical vagotomy was found to reduce significantly the water intake of rats under conditions of ad lib food and water intake and during food deprivation. Vagotomy had no effect on hypovolemic drinking produced by polyethylene glycol injection. In addition, animals with right cervical vagotomies showed a significantly greater urine output than did controls or animals with left cervical vagotomies.

It has become increasingly apparent in recent years that no single physiological mechanism can account for drinking

behavior under all of the varied conditions that give rise to an increased water intake. For example, Cannon's (1918) xerostomic, or dry mouth, theory of thirst was based largely on the observation that desalivate dogs show an excessive water intake when

placed in a warm environment. It is probably true that an excessively dry mouth serves as a stimulus for water intake, but this appears only under special conditions. Cannon's result is complicated by the fact that the profuse salivation of dogs under heat stress, coupled with hypernatremia, serves as a thermoregulatory function and thus may be totally unrelated to mechanisms regulating water balance. Also, salivarectomized dogs (Fehr, 1862; Montgomery, 1931) evidence no excessive water intake over periods of weeks at normal room temperature.

Desalivation in rats, on the other hand, does lead to an excessive water intake when the animals are feeding on a dry diet (Epstein et al, 1964; Vance, 1965). In this case, the increased "thirst" is associated with an exaggerated prandial drinking, the animals using large amounts of drinking water to facilitate the swallowing of dry food.

Quite apart from these oral factors is the elicitation of drinking by osmotic stimuli, notably, hypertonic sodium-chloride solutions. Whether injected peripherally (Gilman, 1937) or centrally (Andersson, 1953; Andersson & McCann, 1955), hypertonic sodium chloride elicits a prompt and prodigious intake of water. Recently, however, it has been possible to separate this sodium, or hypernatremic, thirst from other dipsogenic conditions. There is an abolition of sodium thirst in animals with bilaterally-transected olfactory bulbs, but no disturbance of water intake in ad lib feeding, during food deprivation, or during hypovolemia produced by sodium depletion (Vance, 1967). Blass (1968) reported a similar absence of sodium thirst in animals with frontal-pole lesions, but no disruption of normal water intake or hypovolemic drinking produced by polyethylene-glycol injection. While Blass found no change in sodium thirst with olfactory-bulb section (there is thus conflicting evidence as to the exact anatomical structures involved), it is clear that the integrity of some anterior forebrain structure is necessary for sodium thirst but dispensable for water intake in response to normal dehydration and hypovolemic thirst. Since the "osmoreceptor" mechanism of hypernatremic thirst is evidently not involved in these last two cases, it is of interest to consider alternative mechanisms mediating "normal" and hypovolemic thirst.

At present, one possible candidate is some type of volumetric mechanism. It is well known that reduction of the extracellular volume by bleeding (Fitzsimons, 1961), by sodium depletion (Holmes & Cizek, 1951), or by

*This research was supported by PHS Grant NB05940.

polyethylene-glycol injection (Stricker, 1969), increases water intake while leaving extracellular osmolarity either unchanged (hemorrhage) or reduced (sodium depletion). Gauer et al (1951, 1954) have hypothesized thoracic volume receptors, probably located in the vascular system, that control the release of antidiuretic hormone. Under positive-pressure breathing, and hence a reduced intrathoracic blood volume, they found a decreased urine output which presumably resulted from an increase in antidiuretic hormone activity. On the other hand, an enhancement of negative intrathoracic pressure (increasing thoracic blood volume) leads to an increased diuresis. There is thus the possibility that these hypothesized thoracic vascular receptors, which apparently alter antidiuretic activity, may also be involved in regulating water intake.

In the present experiments, this possibility was explored by assessing the effects of cervical vagotomy on the water intake of the rat.

METHOD

The initial objective of obtaining a preparation with bilateral divisions of the vagi proved fruitless. Animals (Sprague-Dawley males) bilaterally vagotomized invariably died even if the right vs left divisions were performed as much as 10 days apart, or if the left vagus was divided below the exit of the recurrent laryngeal nerve. Permanent tracheostomy also was ineffective, the primary cause of mortality in all cases being an excessive pulmonary edema coupled with extreme difficulty in deglutition. Consequently, the experiments were conducted on animals with only unilateral cervical vagotomies, either right or left. In addition, observations were also made on three animals with left supradiaphragmatic vagotomies.

All animals were housed individually in wire mesh cages fitted with drinking tubes consisting of inverted 100-ml cylinders with a rubber stopper and curved metal spout projecting into the cage. The operations, performed under ether anesthesia, consisted of locating and dividing either the right or left vagus in the cervical region through an incision on the ventral throat. For the supradiaphragmatic vagotomies, the animals were artificially resuscitated.

All cervical vagotomized animals were given a 2-week postoperative recovery period. Water intake was measured to the nearest milliliter, and all values are expressed in terms of ml/100 g body weight. Water intake was measured under conditions of ad lib feeding, food deprivation, and following hypovolemia produced by polyethylene-glycol injection.

In addition, urine output was measured over a 24-h period of food and water deprivation. For each observation, there were six animals in each group (right vagotomies, left vagotomies, and unoperated controls).

RESULTS AND DISCUSSION

Ad Lib Water Intake

Commencing 2 weeks after the operations, the water intake for experimentals and controls was determined under ad lib feeding conditions for a period of 1 week. For right vagotomized, left vagotomized, and controls, the average daily water intake was 7.3, 6.2, and 9.2 ml/100 g body weight, respectively, with both vagotomized groups differing significantly ($p < .001$) from normals.

Water Intake

During Food Deprivation

The total water intake during a 72-h food-deprivation period was 3.1, 6.2, and 8.2 ml/100 g body weight for right vagotomized, left vagotomized, and controls, respectively. The right vagotomized group was significantly different from the left vagotomized group ($p < .02$), and both right and left vagotomized groups were significantly lower than controls ($p < .001$ and $p < .01$).

Urine Output

Urine volumes for a 24-h period of food and water deprivation, immediately following a 3-day period of ad lib food and water, were, respectively, 3.01, 1.80, and 1.61 ml/100 g body weight for the right and left vagotomized groups and the controls. The urine volume for the right vagotomized animals was significantly greater than both the left vagotomized group and the controls ($p < .001$ and $p < .005$).

Hypovolemia

A reduction of the extracellular fluid volume was induced by intraperitoneal injection (1 ml/100 g body weight) of 40% polyethylene glycol (Union Carbide, Compound 20M). There were no significant differences in the water intake of the three groups measured over a 4-h postinjection period, all groups showing a significant increase in water intake.

These results suggest that vagal afferents are important in regulating water intake and also in the control of ADH secretion. Furthermore, the laterality of the vagal section is important since right vs left section produced differential effects on both water intake and urine output. It is of interest that animals with right vagotomies drink significantly less than do normals, both under conditions of ad lib feeding and food deprivation, while at the same time evidence a significantly greater urine output during food and water deprivation.

The question of possible "volume receptors," such as postulated by Gauer et al (1951, 1954), finds difficulty in the fact that the increased water intake seen in the hypovolemia engendered by polyethylene glycol is unaffected by vagal section. With respect to the location of such possible receptors, however, it should be noted that left, supradiaphragmatic-vagal section had no effect on water intake, and it is therefore reasonable to conclude that whatever is responsible for the effect requires an intact vagal innervation of the thoracic cavity.

In summary, unilateral vagotomy leads to significant differences in ad lib water intake, water intake during food deprivation, and urine output, but does not affect water intake in response to hypovolemia.

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