THE MECHANISM OF WATER DIURESIS

THE IMPORTANCE OF THE HYDREMIC FACTOR IN THE REMOVAL OF EXCESS FLUID

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The increase in diuresis after drinking has long since been explained by the "dilution" of the blood following the absorption of a large amount of water from the gastro-intestinal tract.

However, the views on the influence of hydremia on diuresis have changed. At first the action of the hydremia was thought to be directly on the kidneys [9], later it was connected with the secretion of the antidiuretic hormone of the hypophysis [15].

There is no united opinion in the literature about the fact of the presence of the hydremia after a water load, or about the importance of hydremia in diuresis. Some authors noted a pronounced hydremia after drinking [3, 12]; others consider it extremely negligible [2, 4]. Molitor and Pick [14] explain the increased diuresis by the increased amount of water in the blood. A. M. Zyukov [3] considers that there is an inverse dependence between hydremia and diuresis, namely, that a greater hydremia corresponds to a lower diuresis. Marx [12, 13] and others did not observe any correspondence between hydremia and diuresis.

It must be noted that the majority of the experiments mentioned have been conducted on humen subjects, from whom it was very difficult to obtain urine at short intervals; because of this the comparison between the degree of hydremia and the amount of diuresis is usually only approximate.

Our aim was to elucidate the following: whether there is a hydremic reaction to a water load and the nature of its character; and whether, if such a reaction does take place, there is a relationship between it and the amount of diuresis.

To determine the degree of hydremia, the majority of the research workers [3, 5, 7, 12] used indirect methods: the erythrocyte count, the determination of the amount of hemoglobin, the plasma portein content (refractometrically) or a combination of these methods. Others [2, 6] consider that the most accurate indicator of hydremia is the dry residue of blood, although its determination takes longer and is more difficult than refractometry or the hemoglobin estimation.

The experiments set up by us, with repeated estimations of the dry fraction of the blood before and after the introduction of a great amount of fluid into dogs (50 ml per 1 kg of body weight), have shown that in the majority of cases the drinking of water produces a variable hydremia. The maximal "dilution" constitutes 5-10% and takes place towards the end of the first hour following the waterload. The degree of the hydremic reaction is not connected with the amount of fluid ingested.

The hydremic reaction was not observed in a number of cases. Thus, in one of the experiments (No. 6) after the dog had drunk 1100 ml of water, the dry residue of the blood remained unchanged during the next 2 1/2 hours.

To determine the relationship between the water content of the blood and the amount of diuresis, the experiments were made on dogs with exteriorized ureters, from which urine was collected every 15 minutes following the water load (natural drinking). At the same time the dry residue of blood was estimated every 30 minutes. During the experiment the dog was standing in a Pavlov stand.*

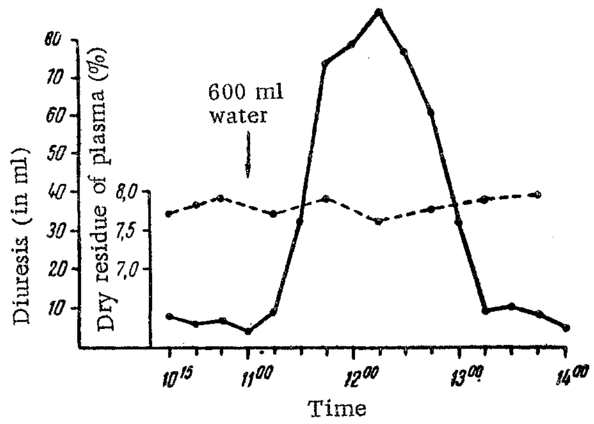

Fig. 1. The hydremic reaction and diuresis following a waterload in the dog Irma (weight 19 kg). Experiment No. 7.

The experiments have shown that the relationship between the diuresis and the hydremic reaction of the blood can be extremely variable. As can be seen in Figure 1, a high degree of diuresis can be observed in the absence of the blood "dilution". In the same cases, when the "dilution" takes place, the diuresis does not have to correspond to the degree of the hydremia. Thus, in experiment No. 9 during an almost indentical lowering of the dry residue, (3.9 and 4.4%) the 15 minute diuresis was 100 and 13 ml respectively.

Thus, we did not establish any direct relationship between the hydremia and the degree of urine secretion.

However, it is possible that the entrance of a great amount of fluid into the blood can serve as a stimulus which gives an impetus to increase the secretory action of the kidneys (the "water shock" after the terminology of the German authors). This apparently corresponds to the well known fact, that the increase of the diuresis takes place 20-30 minutes after drinking.

To make this more precise, it was of interest to compare the excretion of fluid after ordinary drinking and after parenteral introduction. It could be expected that the fluid introduced subcutaneously and especially intravenously would produce a greater diuresis, and that the urine secretion would, in any event, take place much sooner than after oral introduction.

However, the literature on this subject states that the liquid introduced parenterally is excreted less readily than that taken by mouth. This was unexpected, especially since the explanations given were not sufficiently convincing. Also, a number of authors hold a different opinion, considering that water or physiological saline given intravenously produce a usual type of diuresis [1, 10].

We have made 39 experiments on 6 dogs with exteriorized ureters. The fluid was given subcutaneously or intravenously and orally in the control experiments. In some cases we combined the subcutaneous and intravenous introductions.

The infusion was made with the Bobrov apparatus at a rate of approximately 20 ml per minute. The water was warmed to the body temperature. The experiments were strated not earlier than 16 hours following the last intake of food, to produce a more constant background.

The findings obtained after the intravenous or subcutaneous introduction of fluid (20-30 ml/kg) have convinced us that the diuresis in this case differs sharply from that observed after ordinary drinking.

The intravenous introduction of the physiological solution produced either a very sluggish and prolonged diuretic reaction (Figure 2), or a typical rise in the urine secretion, but after a considerable delay. Thus from Figure 3 it can be seen that after drinking the increase in the diuresis took place after 15 minutes, whereas after intravenous infusion of an approximately equal amount of fluid, it took place after 1 hour 15 minutes.

The excretion of the water injected subcutaneously occurs later, in spite of the fact that its passage into the blood, as is known, takes place rapidly (it was easy to see this by palpation — by the disappearance of the swelling).

*Such an arrangement of the experiment has a undoubted advantage over Marx's method [13] who collected the urine by an indwelling catheter and introduced the water through a tube; during this the dogs were tied to a table.

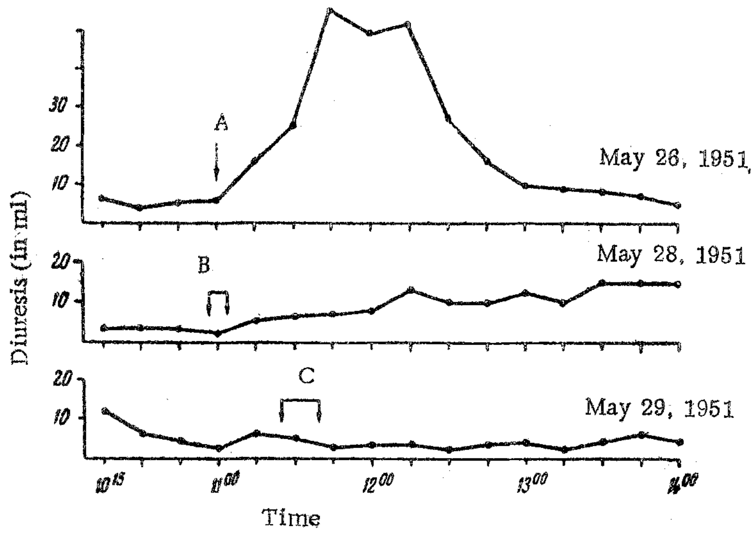

Fig. 2. Diuresis in dog Zlyuka (weight 9 kg) with various methods of fluid introduction. Introduced: A) by mouth 300 ml water; B) intravenously 200 ml physiological solution; C) subcutaneously 250 ml physiological solution. Here and on the other diagrams the arrows indicate the beginning and the end of the introduction.

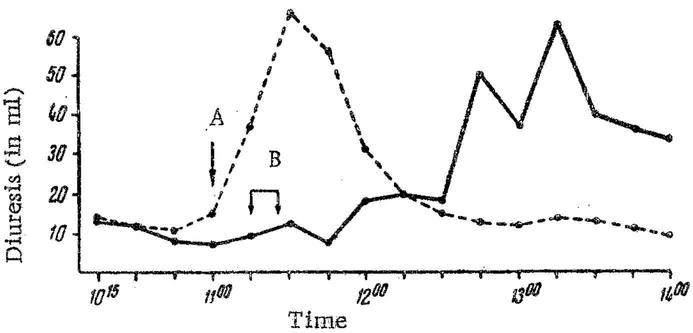

Fig. 3. Diuresis in dog Irma (weight 19 kg) with various methods of water introduction. Introduced: A) 300 ml water by mouth (average of 4 experiments); B) 270 ml of physiological solution intravenously (experiment No. 14).

In experiment No. 16, 400ml physiological solution was introduced perenterally into dog Irma (partly intravenously, partly subcutaneously). The rise in the diuresis began after a delay, and after 3 hours (counting from the middle of the interval between the beginning of the intravenous and the end of the subcutaneous injection) 36% of the fluid introduced was excreted, after which the urine secretion became even and the excess diuresis stopped.

It could be considered that the low excretion of the physiological solution after parenteral introduction depends on the entrance into the organism of salt, which retains water. From this point of view it would be interesting to use an isotonic glucose solution for intravenous infusion. As is pointed out by Wolf [16] the rapid removal of glucose, in connection with its being drawn into the metabolic process, makes this load similar to the pure water load and causes a much greater decrease in the osmotic pressure of the tissue fluid than the salt solution.

In experiments with the intravenous introduction of a 4.9% glucose solution in the usual amount (20-25 ml/kg) the diuresis did not differ in any way from the diuresis after the introduction of the salt solution (in any case it was not greater). Thus, for example in dog Krasotka (weight 14 kg) the diuresis during 2 hours after the introduction of 300 ml of the physiological salt solution was 163 ml, and after introducing glucose solution 153 ml. After a subcutaneous injection of 400 ml of the glucose solution into dog Damka (weight 19 kg) there was no increase in the diuresis during the next 5 hours; similar results were obtained after a subcutaneous injection of the same amount of a physiological salt solution.

Thus, fluid introduced parenterally is, as a rule, excreted from the organism later than fluid taken by mouth, which again confirms the earlier obtained data against the hydremic theory of diuresis.

What, then, is the reason for this phenomenon?

Cow [8] proposed that water drawn up from the intestine takes with it a special hormone, which stimulates diuresis (probably indirectly through the hypophysis). Because of this, he injected an extract of the mucosa of the stomach and of the intestinal tract, or added it to the water introduced parenterally, and noted an increase in diuresis.

Hashimoto [11] produced a diuresis by the addition of 0.45% of sodium chloride to water introduced parenterally; he considered that water when it was drawn up from the intestine took with it salts which produced a high diuresis. However, further experimental findings were against these explanations.

The hypotheses quoted, and other suppositions, seemed somewhat inconvincing because they also ingnored the nervous system, which draws the function of the organism into correspondence with the changes in the external environment.

To us it seemed doubtless that in the process of phylogenesis there must have developed neuroreflex mechanisms, which ensure the excretion of excess fluid from the moment it enters the organism. Considering that the only natural way for water to enter the organism is by mouth, we presumed that the introduction of water into the gastrointestinal tract can in its own right have a significance in stimulating diuresis, similar to the fact that food can provoke a series of reflex reactions directed towards its assimilation before entering the stomach. The experimental verification of this presumption is the subject for further work.

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