EFFECT OF ACUTE ENVIRONMENTAL HEAT STRESS ON URINARY WATER AND ELECTROLYTE EXCRETION IN THE RAT

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Summary : Plasma cortisol and urinary excretion of water, sodium, potassium, calcium and magnesium have been studied in the rat after application of heat stress. There was a significant increase in plasma cortisol level after exposure to heat. During heat stress complete cessation of urine formation was observed. In the next 30 min there was statistically significant increase in the urinary excretion of water, sodium and calcium but not of potassium and magnesium. Urinary calcium/magnesium ratio was also significantly elevated. The increase in urinary water and electrolyte excretion seemed to be mediated through prostaglandins since it could be abolished by administration of indomethacin prior to the application of heat stress. On the basis of these results, the possible role of heat stress in the genesis of urolithiasis has been discussed.

Key words : heat stress, cortisol, urinary electrolytes, renal prostaglandins, urolithiasis

INTRODUCTION

Reduction in glomerular filtration rate leading to a decrease in urinary water and sodium excretion has been observed in human subjects exposed to heat stress (12). Increased plasma levels of cortisol, antidiuretic hormone (A. D. H.) and aldosterone (8, 10, 15) observed during heat stress may contribute to the changes in the urinary water and sodium excretion. However, the effect of acute heat stress on urinary calcium and magnesium excretion has not been reported. Such a study is warranted by the facts that (a) urinary calcium/magnesium ratio has been implicated in the genesis of urolithiasis (7, 20) and (b) the incidence of crystalluria and urinary stone disease is far greater in summer than in winter (21, 22, 23).

MATERIAL AND METHODS

The study was conducted on female rats weighing 200-250 *g* each, between 9.00 A.M. and 2.00 P.M., during the months of October to February. The rat was anesthetised by

intraperitoneal injection of 30-40 *mg/kg* nembutal. Throughout the experiment normal saline was infused into a tail vein at the rate of 5 *ml/hr* with the help of continuous slow injector (INCO). A fine polyethylene catheter was introduced into the bladder and tied at the urethra. After allowing 90 min for equilibration, seven 30 min urine samples were collected, i.e. two basal samples, one during heat stress and 4 samples subsequently. Each sample was analysed for volume, sodium and potassium by flame photometry, magnesium by the method of Orange and Rhein (19) and calcium by the method of Connerty and Briggs (5).

In 10 rats heat stress was applied by placing the animal in an incubator at 45°C for 30 min. In another group of 5 rats, the procedure was repeated 30 minutes after intragastric administration of indomethacin, 5 *mg/kg* body weight (24).

In 5 rats each, three intracardiac blood samples were taken, just before and after application of heat stress and another 120 minutes later. Another group of 5 rats, not exposed to heat stress, served as control for plasma cortisol estimation. Plasma was analysed for cortisol level by the enzyme immunoassay (ELISA) technique according to the principle of Engval and Perlmann (6). The data was analysed by paired 't' test.

RESULTS

Basal mean rectal temperature was 36.63°C±0. 15SE. After 30 minutes of heat exposure, it rose to 40.04°C±0. 07SE. Two hours after the end of heat exposure, mean rectal temperature returned to the basal level (36.90°C±0.16SE). The heat stress produced a marked increase ($P<0.001$) in plasma cortisol level (Table I).

TABLE I : Effect of heat stress on plasma cortisol (mean±SE). Plasma samples were obtained before (A), just after (B) and 120 minutes after application of heat stress (C).

	Plasma Cortisol µg/100 ml		
	(A)	*(B)*	*(C)*
Heat stress (n=5)	10.45±1.25	40.57±2.06**	15.71±1.71*
Control (n=5)	10.67±1.45	13.01±1.89NS	12.13±1.51NS

NS = Not significant, * $P<0.05$, ** $P<0.001$, paired 't' test compared to (A).

Urinary Volume and Electrolytes : Exposure to heat stress led to almost immediate and complete cessation of urine formation in all the rats (Fig. 1). Urine flow was resumed soon after the rats were taken out of the hot chamber and during the next 30 min, urinary volume was significantly greater than the basal excretion ($P<0.001$). During this period of polyuria urinary sodium and calcium excretions were also significantly increased ($P<0.02$) but the increase in urinary magnesium and potassium was not significant. Consequently urinary calcium/magnesium ratio was significantly elevated ($P<0.05$).

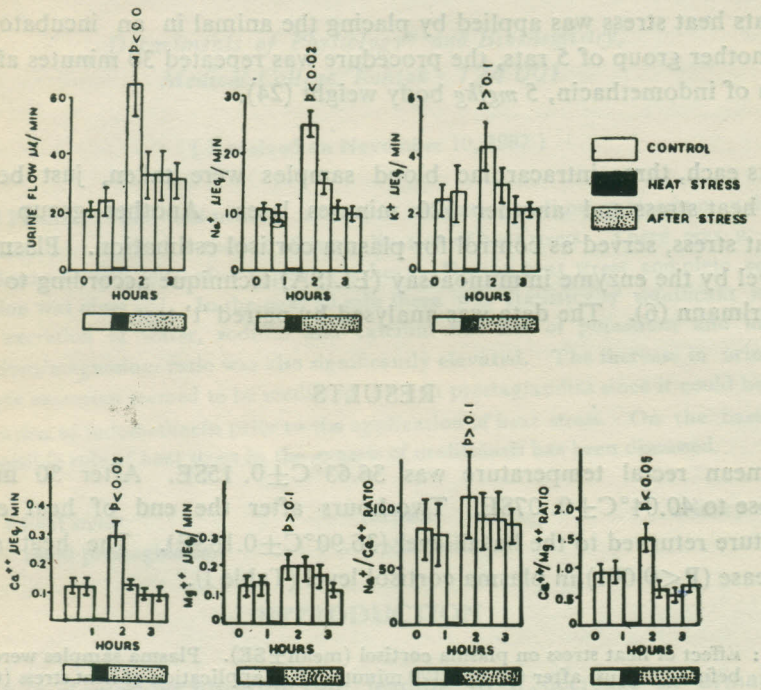

Fig. 1 : Effect of heat stress on urinary water and electrolyte excretion (Mean±SE).

After administration of indomethacin, complete anuria occurred during heat stress but polyuria, naturesis and calciuresis were not observed subsequently.

DISCUSSION

Severe reduction in urine flow and sodium excretion has been observed earlier in men exposed to acute heat stress and attributed chiefly to a reduction in the renal blood flow and glomerular filtration rate (12). The reflex alteration in renal haemodynamics may be expected in view of the reported massive increase in cutaneous blood flow on exposure to heat (13).

This study has shown that even complete cessation of urine formation may occur during acute exposure to heat stress.

Increased antidiuretic activity of plasma has been observed in the rat and men exposed to hot environment (8, 10). In the rat with hypothalamic lesions leading to diabetes insipidus, heat exposure was not as effective in reducing the urine flow as in the case of normal animal (9). Therefore in heat stress, increased secretion of A.D.H. may also contribute to the reduction in urinary volume especially after prolonged heat exposure.

The significant increase in plasma cortisol observed in the rats exposed to heat stress is an expected finding. Earlier Collin *et al.* (4) have observed marked increase in plasma cortisol in men after 2 hours but not after 1 hr of heat exposure. However, increase in plasma corticosteroids can not explain the alterations in the urine (i. e. ployuria, naturesis and calciuresis) observed after the heat exposure. Corticosteroids tend to produce sodium and water retention whereas, we have observed significant increase in their excretion. Moreover cortisol is reported to have no acute effect on urinary calcium and magnesium excretion (14).

Administration of indomethacin prior to the exposure to heat stress completely abolished the polyuria, naturesis and calciuresis. Therefore, renal prostaglandins, produced during stress (13), seem to be responsible for the increased urinary water, sodium and calcium excretion. Similar urinary changes (except initial anuria) were observed by us in rats exposed to acute neurogenis stress (17). Moreover an increase in renal blood flow as well as urinary sodium, water and calcium excretion has also been observed after intrarenal administration of prostaglandins (1, 2).

There seems to be a genetic predisposition to renal stone disease (3, 16). However, an environmental factor is required to trigger the initiation of stone formation. Since environmental temperature exceeds 45°C on many occasions during summer in northern India, heat stress may be one of such factors. Normal urine is appreciably supersaturated with respect to calcium and oxalate but the stone formation is prevented by the presence of one or more low molecular weight inhibitors like magnesium and inorganic pyrophosphate (18). An increase in the urinary calcium/magnesium ratio can disturb the balance between the saturation and inhibitory factors and initiate the process of stone formation (7, 11, 20). Therefore, increased incidence of urolithiasis in summer may be due to two factors :—

(a) Heat as a form of stress may increase the urinary calcium/magnesium ratio
(b) During the stage of transient oliguria/anuria the reabsorption of tubular fluid in the collecting ducts may lead to extreme supersaturation and spontaneous precipitation of calcium

oxalate, constituting the nucleation phase of urolithiasis. Subsequently if the crystals are trapped in a narrow point in the urinary tract, crystal growth and aggregation may gradually occur ultimately forming a renal stone.

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