Study of Relationship between pH of Urine and Sodium and Potassium Excretion.* (20596)

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A normal, characteristic pattern of diurnal pH variation has been recognized since the middle of the last century(1), but to date its occurrence has not been satisfactorily explained. Hubbard and Steele(2) found that awakening in the morning caused a rise in urinary pH. This "alkaline tide" is independent of meals. Ryberg(3) observed a drop in pH immediately following a meal. Two to 4 hours after a meal, urinary pH rises(4,5). The secretion of gastric juice, changes in respiration, as well as secretion of pancreatic juice have all been factors considered important in this phenomenon. Stanbury and Thomson(6) have shown a clear parallelism between urinary pH, sodium, potassium, chloride and bicarbonate. They also found that diurnal excretory rhythm persisted in the face of starvation, water deprivation, salt deprivation, sustained action of desoxycorticosterone, pituitary antidiuretic hormone, and temporary disturbance of the sleep rhythm.

In the course of a study on the effect of adrenalin on the kidneys(7,8), it was found that a patient with a low sodium output showed a lack of diurnal variation in the pH of urine. The addition of salt to this patient's diet resulted in increased sodium output and restored a completely normal pattern of alkaline tides. This observation prompted a series of experiments concerned with urinary sodium and potassium excretion and their relation to the variation in urinary pH.

Methods. Twenty-three male medical students and 23 postoperative patients were used in this study. Serum sodium was determined in nearly all subjects. The students voided once every hour for at least 8 hours (8 A.M. to 4 P.M.) and the urine was analyzed for sodium, potassium, ammonia, chlorides and titratable acidity. The pH was determined immediately on the freshly voided samples but no precautions were taken to avoid CO_2 loss. In all the patients, an indwelling catheter was placed in the bladder and continuous recording of the pH of the urine was carried out for a minimum period of 8 hours (8 A.M. to 4 P.M.). A recording pH meter which has been described previously(7,8), or a smaller portable unit,† was used for the continuous determination of pH. The urine samples from the patients were collected every hour and the pH was determined on these pooled samples without attempting to prevent the loss of CO_2. Since the continuous determination of pH took place in a closed system, pH differences between the urine in the closed and open system would have indicated the CO_2 loss which had taken place. One would expect a difference in the magnitude of the pH variations using the 2 different methods of collection. If an increase and a decrease in pH occurred within an hour, a pH determination on samples collected hourly would tend to nullify the variations. Nevertheless, a comparison of the 2 methods over a minimum period of 8 hours, showed that a lack of variation seen with one method, would also be revealed by the other. Furthermore, the degree of variation in pH using the continuous recording system, compared fairly well with that of the determination on the samples collected every hour. Since this study deals with the degree of pH variation over a minimum period of 8 hours, this variation will, for convenience, be expressed as the standard deviation of the pH's of the samples collected hourly. Thus, a standard deviation of 0 to ± 0.2, indicated a lack of normal variation in the pH of the urine. Normal diurnal variations result in a higher standard deviation. Sodium and potassium in

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† The Macbeth Corp. Newburgh, N. Y., has generously cooperated with us in making a small unit designed for the purpose of continuously reading the pH of urine.

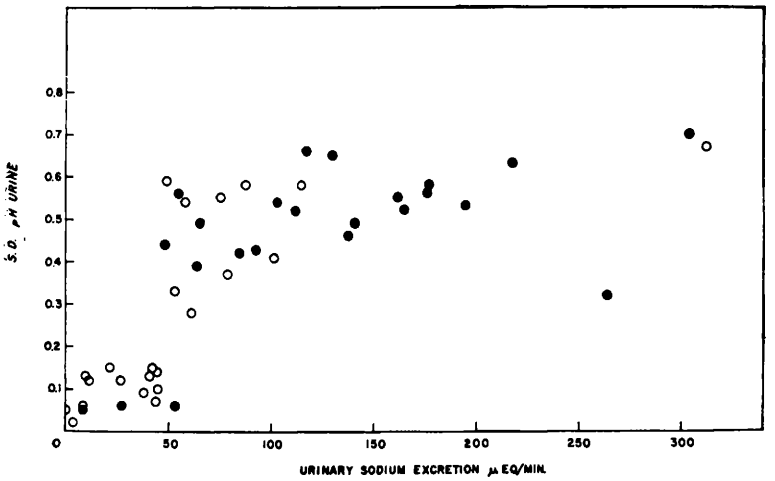

FIG. 1. Correlation of urinary pH variations with mean sodium excretion per min. for a minimum period of 8 hr. Variations in urinary pH are expressed as stand. dev. and it can be seen that 16 patients had very little, or no variation in pH of urine. Circles indicate patients, black dots represent normal subjects.

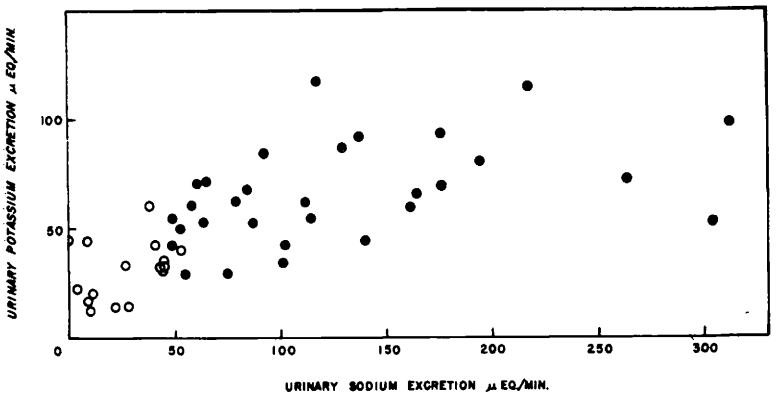

FIG. 2. Correlation between mean excretion of potassium per min. and mean excretion of sodium per min. during a minimum period of 8 hr. Circles represent all cases in which minimal or lack of urinary pH variation was seen, black dots represent the cases exhibiting normal variations.

the hourly urine samples as well as in serum were determined using a Beckman Spectrophotometer model DU with flame photometer attachment. The urine samples were also analyzed for chloride(9), titratable acid(10) and ammonia(11).

Results. In Fig. 1, variation in the pH of the urine expressed as standard deviation of pH is plotted against urinary sodium excretion per minute. It can be seen that when sodium excretion drops below approximately 45 microequivalents per minute, normal pH variation is not observed. Fig. 2 shows the relationship between the mean excretion of sodium and the mean excretion of potassium per minute. In most instances when the standard deviation of the pH of the urine was low, the mean excretion per minute of potassium was also below 45 microequivalents. This figure also shows that only in one of 16 cases with low pH fluctuation was the mean sodium excretion marginally above 45 microequivalents per minute. Of the cases with a potassium excretion below 45 microequivalents per minute, 5 had a normal urinary pH variation.

An attempt to correlate the pH variations with the mean excretion per minute of ammonia and titratable acidity yielded no definite

relationship between either of the two. However, all the subjects exhibited an excretion of titratable acid within normal range.

All of the 16 subjects which exhibited a relatively fixed urinary pH with no or only minimal variation, had an acid urine. However, the actual pH varied considerably from individual to individual (4.8-6.0). Therefore, no correlation was found between the sodium excretion and the actual pH of the urine.

Discussion. The mechanism accomplishing acidification of the urine, according to Pitts (12,13), involves the carbonic anhydrase catalyzed hydration of carbonic acid and a process of ion exchange. Since the administration of the carbonic anhydrase inhibitor 6063 (Diamox) can result in a sodium diuresis which is greatly in excess of that which could be accounted for in terms of hydrogen ion exchange, it must be assumed that carbonic anhydrase is responsible in some additional way for a much greater reabsorption of sodium than has hitherto been assumed. This has recently been suggested by Pitts(14).

If this is true, it would follow that maximum activity in the systems involving carbonic anhydrase should result in maximum reabsorption of sodium and maximum production of hydrogen ion, the latter probably being responsible for the fixation of urinary pH on the acid side.

The results obtained in this study indicate that a fixed acid urine is concomitant with a high reabsorption of base. This would be expected if the above mentioned theory is correct.

The data in this paper have been utilized clinically to evaluate excretion of base. It has been a constant observation that patients exhibit water and salt retention as long as they maintain a fixed urinary pH provided that titratable acidity is not exceedingly high (above 25 microequivalents per minute). This has repeatedly been observed in cases of traumatic shock. In cases where it has been possible to restore normal pH fluctuations, this has been concomitant with sodium diuresis leading to water and salt balance. Much work remains to be done along these lines but so far it has been possible to utilize this technic with great advantage in some severely burned patients(15). It is worthwhile to emphasize that only patients with supposedly normal kidneys have been considered and it is doubtful whether the correlation described in this study will have bearing in patients with renal damage.

Summary. Urinary pH was determined hourly for a minimum period of 8 hours in 46 cases. The urine samples which were collected every hour were analyzed for sodium, potassium, ammonia, chloride and titratable acidity. A definite correlation between sodium-potassium excretion and variation in pH of the urine was established. All 16 exhibiting a sodium excretion below 45 microequivalents per minute had a fixed urinary pH at a level which differed considerably from individual to individual. Only one person with a slightly higher sodium excretion (53 microequivalents per minute) had a fixed urinary pH. Potassium showed a similar pattern although less consistent, since 5 subjects with normal pH variations had a low potassium excretion.

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