THE SIGNIFICANCE OF URINE CHLORIDE DETERMINATION IN THE DETECTION AND TREATMENT OF DEHYDRATION WITH SALT DEPLETION*

K. KELLER VAN SLYKE, M.D., AND EVERETT IDRIS EVANS, M.D., PH.D.

WITH THE TECHNICAL ASSISTANCE OF

MISS RACHEL LEWIS AND MISS RUTH TAYLOR

FROM THE SURGICAL RESEARCH LABORATORY, MEDICAL COLLEGE OF VIRGINIA, RICHMOND, VIRGINIA.
THIS STUDY WAS CARRIED OUT UNDER A GRANT FROM THE OFFICE OF RESEARCH AND INVENTIONS, UNITED STATES NAVY.

THE PHYSICIAN FREQUENTLY faces the problem of how much and what kind of parenteral fluids to administer; in most cases the problem is the quantitative one of how much water and how much salt the patient needs. Neither physical examination nor estimation of plasma chloride concentration gives adequate information. However, our experiments with dehydrated human subjects indicate that, when renal or adrenal function is not damageed, the problem can be solved by measuring the urine volume excretion and urine chloride concentration, both of which are bedside determinations.*

The physiologic principles of water and electrolyte balances, which have been developed especially by the work of Gamble[2] and Peters,[3] are well reviewed by Mariott.[4] Body water may be regarded as separated into three compartments: plasma, interstitial tissue fluid, and intracellular fluid (Fig. 1). Body electrolytes may be regarded as separated into two compartments: intracellular and extracellular, the latter corresponding to the plasma plus interstitial spaces (Fig. 2). Roughly speaking, the capillary membrane is freely permeable to water and electrolytes while the cell membrane is freely permeable to water alone. Equality of osmotic pressure throughout the body fluids, intra- and extracellular, is maintained by water shifts across all membranes and electrolyte shifts across the capillary membrane. The shifting extracellular electrolyte is predominantly sodium chloride (Fig. 2). Under ordinary conditions, the kidneys adjust excretion of water, and sodium chloride and other solids so accurately to intake that the volume and electrolyte concentration of the extracellular fluid are kept extraordinarily constant, providing the cells with the "internal environment" of Claude Bernard. For the cells to function normally, the volume of extracellular fluid must be kept adequate, and the

* By the method of Fantus,[1] urine chloride concentration can be quickly measured at the bedside with an accuracy of plus or minus 0.5 grams NaCl per liter of urine. The necessary apparatus and solutions are: a test tube, a medicine dropper, 20% potassium chromate, 2.9% silver nitrate, and distilled water for rinsing the dropper. To 10 drops of urine in a test tube, add 1 drop of potassium chromate solution and then silver nitrate solution, a drop at a time with shaking until the test tube contents suddenly change from yellow to brick red. The same dropper must be used throughout and rinsed between solutions. The number of silver nitrate drops required to produce the color change equals the urine sodium chloride concentration in grams per liter. Tests on 50 random hospital urine samples gave an average of 7.37 Gm. NaCl per liter urine with variations from 1 to 16 Gm. per liter.

* Read before the American Surgical Association, May 27, 1948.

composition and pH must be kept within "physiological" limits; the osmotic pressure must be kept near that of 0.9% NaCl solution.

Local deviations from isotonicity are prevented by rapid water and salt shifts within the body; abnormal changes in the volume or composition of the total body fluids are prevented by the kidneys. When either water or salt intake is low or extra-renal loss is excessive, isotonicity is safeguarded by a corresponding decrease in either water or salt output by the kidneys. When renal mechanisms are normal one may expect to find small urine volumes with water depletion and low urine salt concentration and excretion with salt depletion. Such relationships are illustrated in the experiment presented below, and form the basis for the plan recommended for guiding parenteral fluid therapy.

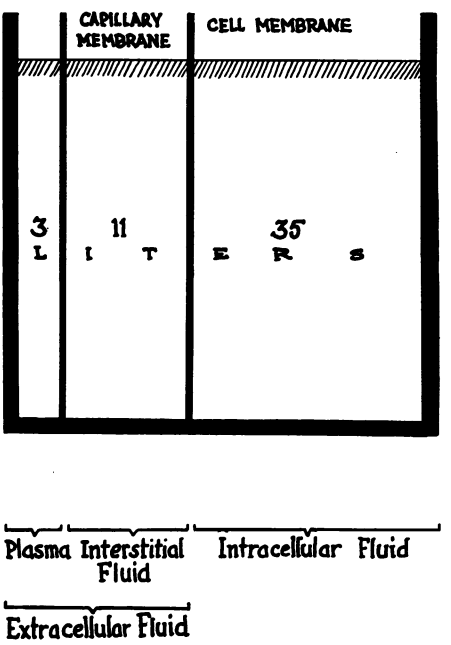


FIG. 1.—Body fluid compartments of normal 70 kg. man.

As Marriott points out,[4] dehydration is a term that covers two conditions that differ in cause, in physiologic and clinical effects, and in treatment needed. These conditions, named according to their initiating causes, are primary water depletion and primary salt depletion. (Marriott calls them "pure" depletion, but the term "pure" seems unfortunate, because salt deprivation or loss invokes accompanying water loss, and water deprivation or loss invokes salt loss.)

Primary water depletion is seen in conditions in which, usually because of generalized weakness or dysphagia, patients fail to drink adequate amounts of fluid. In debilitated patients it occurs more commonly than is recognized. The chloride concentration of the plasma may remain normal; the kidneys usually excrete enough salt to maintain extracellular isotonicity.

Primary salt depletion occurs when there is abnormal loss of salt from the body with adequate water intake. The salt loss may occur in profuse sweating, excessive vomiting, gastric suction, diarrhea or alimentary tract fistulae.* Since the kidneys will not retain water without salt until the salt loss is severe, depletion of body water occurs, even if adequate amounts of water are drunk. Thus, though total body salt may be depleted, plasma chloride concentration

* The discussions and conclusions set forth in this writing do not pertain to the unusual electrolyte maladjustments encountered in Addison's disease.

may remain relatively normal so long as the extracellular fluid volume diminishes enough to compensate for the salt loss, and water excretion may remain adequate despite diminished extracellular fluid volume.

Figures 3 and 4 (taken from Marriott) show the theoretical water redistributions between the body compartments in primary water and primary salt depletion respectively.

With *primary water depletion* (Fig. 3) the extracellular fluid tends to become *hypertonic,* but this tendency is combated by two mechanisms; water moves across the cell membrane into the extracellular space, and the kidneys diminish their water output to the minimum obtainable by tubular reabsorp-

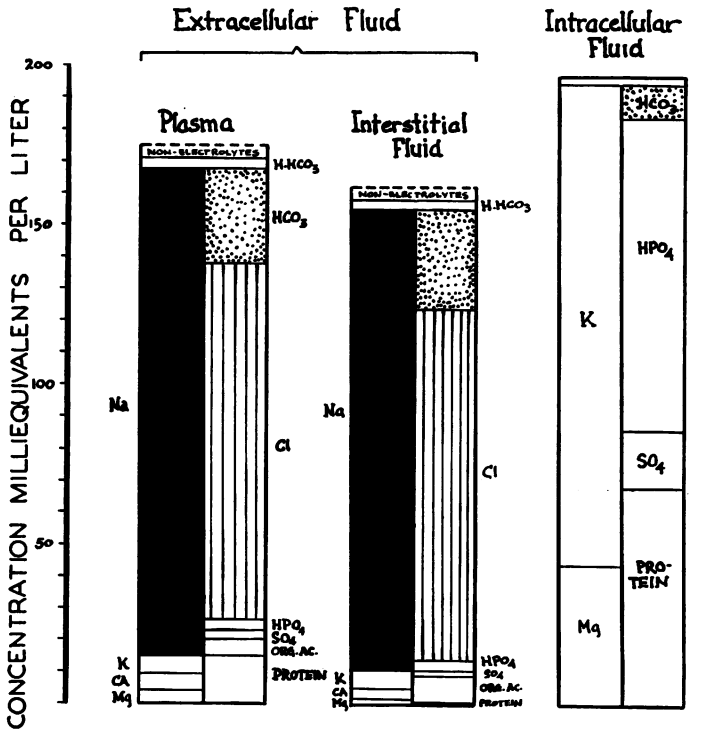


FIG. 2.—Composition of body fluid compartments of normal man.

tion. Although intracellular dehydration is marked, there may be no great change in either the plasma volume or electrolyte concentration. In this condition one may expect a *minimal urine volume,* normal or increased plasma and urine chloride concentrations, and no cardiovascular changes referable to diminished plasma volume.

With *primary salt depletion* (Fig. 4) the extracellular fluid tends to become *hypotonic.* The kidneys exert themselves to combat this tendency; *they continue to excrete water but practically no salt.* Plasma chloride concentration falls only when the kidneys can no longer excrete enough extracellular water to compensate for the salt loss. When plasma chloride con-

centration does fall, the loss of body water may be greatly out of proportion to the relative decrease in plasma chloride concentration. Shrinkage of plasma volume may become so great that clinical shock may develop.

In both primary water depletion and primary salt depletion, the kidneys exert maximum efforts to maintain isotonicity of the plasma and interstitial fluids, and in these efforts excrete urine that shows variations in volume and salt concentration greatly exceeding the variations in volume and salt concentration that occur in the plasma. The decrease of water excretion in pri-

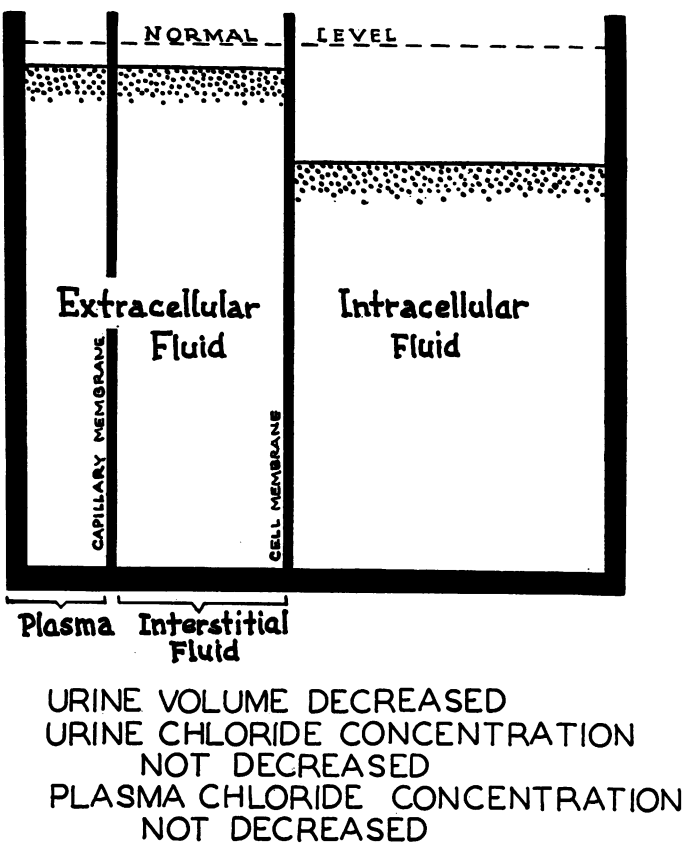
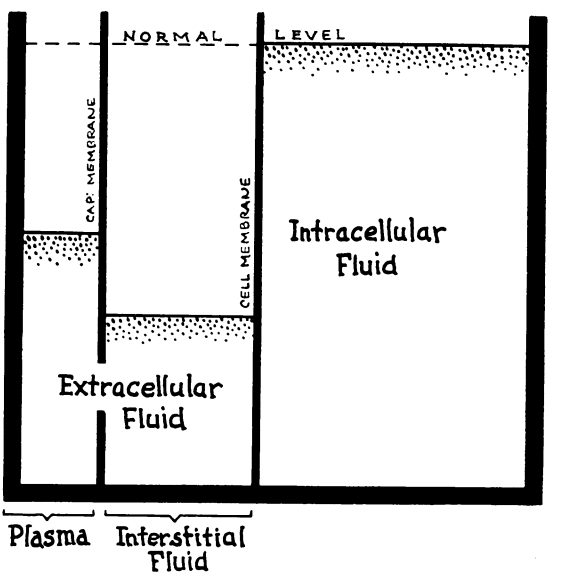


FIG. 3.—Water depletion.

mary water depletion, and of salt excretion in primary salt depletion, becomes marked when the plasma changes have hardly exceeded the normal range. Hence, it appears that, provided the kidneys are uninjured, urinary analyses can provide more sensitive indication of the occurrence and type of dehydration than can plasma analyses; that is, urine analyses can be expected to show earlier and more definitely than plasma analyses when body conditions change in either type of dehydration, from the normal to the abnormal.

On the other hand, since the kidneys respond early with nearly maximal limitation of water or salt output, it follows that urine analysis cannot be relied on to show the difference between moderate and severe dehydration of either type. The severity of the depletion may be determined either by observing the amount of water and salt therapy required to reestablish the excretion of water or salt, or by plasma measurements such as chloride and CO_2 concentration, specific gravity and blood hematocrit.

When the kidneys are diseased, or injured by shock or severe dehydration, the urine probably does not indicate internal conditions of salt and water content as accurately as when the kidneys are normal. Even kidneys which have been apparently normal one day, may, as the result of a transitory period of shock, be so damaged that the next day they excrete only a small volume of urine with little solids of any kind. This may occur in the immediate post-



URINE CHLORIDE CONCENTRATION DECREASED
PLASMA CHLORIDE CONCENTRATION NOT DECREASED UNTIL SALT DEPLETION IS GREAT

FIG. 4.—Salt depletion.

operative patient. Possibly salt retention postoperatively and during times of stress may result from the so-called "alarm reaction," a physiological state resulting from adrenal hormone secretion. Coller[5] and Moyer[6] have shown that postoperative patients tend to retain salt, and they have cautioned against overloading the patient with salt. Urine salt concentration or excretion cannot be used as a guide to salt therapy under conditions of renal salt retention. Further studies are needed to determine the conditions under which the kid-

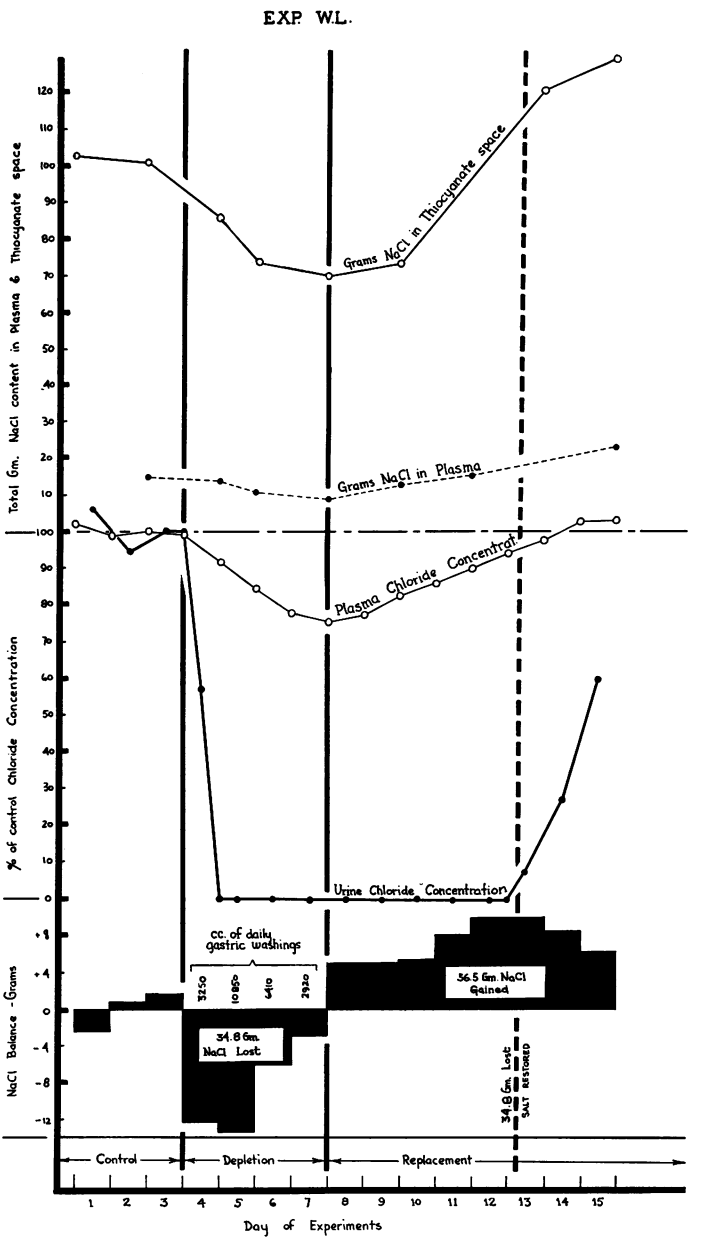


FIG. 5.—Human volunteer experimental demonstration of water and salt depletion showing (1) the renal threshold level of about 95 percent normal plasma chloride concentration, (2) the greater sensitivity of urine chloride concentration as opposed to plasma chloride concentration as an index of salt depletion and replacement, (3) the excessive water and salt retention resulting from continued saline infusions after chlorides reappear in the urine.

neys do retain salt. Further studies are also needed to rule out the possibility of salt "spillage" into the urine during and following saline infusion. Such spillage could falsely indicate adequate salt replacement.

In the great majority of cases of dehydration encountered, however, urine analysis serves well to indicate early the occurrence and type of dehydration and to indicate when therapy is necessary or has been adequate to return the volume and salt content of the plasma and interstitial fluids to their normal ranges.

EXPERIMENTAL PROCEDURE

The following experiment, which is one of three, illustrates the applicability of the above principles in a case of mixed salt and water depletion caused by prolonged gastric suction.

W. L., a healthy medical student, voluntarily subjected himself to a carefully controlled 15-day water and salt balance study. This study (Fig. 5, Tables I, II, and III) may be divided into three periods: (1) Preliminary control—the first three days. Daily measurements were made during this control period and their average taken as "control." (2) Depletion period or period of gastric suction—the next four days. Constant gastric suction during this period produced a marked mixed water and salt depletion. Water was drunk as desired but was all recovered by gastric suction. No parenteral fluids were administered. (3) Replacement period—the last eight days. Water was drunk as desired. Salt depletion was slowly overcome by a measured dietary intake (0.8 to 1.2 Gm. NaCl daily), supplemented by intravenous 0.9% saline. The salt supply of the body was replaced slowly in order to increase the number of days over which the replacement could be observed. Five hundred cc. of 0.9% saline (4.5 Gm. NaCl) solution were given daily for three days, but since complete replacement appeared unlikely within the 15 days available for the experiment, daily 0.9% saline solution administration was increased to 750 cc. on the fourth day and to 1000 cc. the last four days. The experiment was ended when plasma chloride concentration no longer increased.

All chloride determinations were done in duplicate, using the open Carius method.[7] The salt intake was measured by chloride determinations of aliquot samples of diet and infusion solutions. Salt output was determined by measuring the volume and chloride concentration of 24-hour urine and gastric suction collections.

In order to compare urine and plasma chloride concentrations on the same chart, they are plotted as "per cent of control," the "control" values being the average of the control period concentrations.

The total salt content of the plasma was measured by multiplying the plasma salt concentration (calculated from chloride) times the plasma volume, the latter being measured with T-1824 blue dye.[8] Total extracellular space salt content was estimated by multiplying the plasma salt concentration by the thiocyanate space volume.[8] Both plasma volume and thiocyanate space determinations were made from six-point disappearance curves using a Coleman Model 6 spectrophotometer.

TABLE I.—*Experiment W. L.—Daily Salt Balance*

Experimental Period	Day of Experiment	NaCl Intake (Gm.) Diet	Tablets	As 0.9% Intravenous NaCl	Total	Gastric NaCl Output: Gastric Washings cc./day	Gastric NaCl Output: NaCl Concentration (Gm./L)	Gastric NaCl Output: Total Gm. NaCl/day	Urine NaCl Output cc./day	Urine NaCl Output: NaCl Concentration (Gm./L)	Urine NaCl Output: Total Gm. NaCl/day	NaCl Output (Gastric Plus Urine)	NaCl Balance (Intake Minus Output)
Control	1	0.84	5	0	5.8	—	—	—	2,210	3.7	8.2	8.2	— 2.4
	2	0.87	3	0	3.9	—	—	—	975	3.3	3.2	3.2	+ 0.7
	3	1.17	3	0	4.2	—	—	—	735	3.5	2.6	2.6	++ 1.6
Depletion	4	0	0	0	.0	3,250	3.34	10.9	735	2.0	1.5	12.4	—12.4
	5	0	0	0	0	10,850	1.25	13.5	490	0	0	13.5	—13.5
	6	0	0	0	0	6,410	0.92	5.9	425	0	0	5.9	— 5.9
	7	0	0	0	0	2,900	0.96	2.8	605	0	0	2.8	— 2.8
Replacement	8	0.49	0	4.5	5.0	—	—	—	1,170	0	0	0	+ 5.1
	9	0.63	0	4.5	5.1	—	—	—	2,140	0	0	0	++ 5.0
	10	0.87	0	4.5	8.0	—	—	—	2,495	0	0	0	++ 5.4
	11	1.20	0	6.8	9.8	—	—	—	1,990	0	0	0	++ 8.0
	12	0.84	0	9.0	9.9	—	—	—	1,980	0	0	0	++ 9.8
	13	0.87	0	9.0	9.9	—	—	—	1,240	0.3	1.3	0.3	++ 9.6
	14	1.20	0	9.0	10.2	—	—	—	1,910	1.8	1.8	1.8	+ 8.4
	15	0.87	0	9.0	9.9	—	—	—	2,270	4.7	4.7	4.7	+ 5.2

Hematocrits were measured in quadruplicate by centrifugation at 3000 RPM for 45 minutes. Plasma total protein concentrations were determined by the copper sulfate specific gravity method of Phillips, et al.[9]

Other measurements were: body weight, urine pH, urine specific gravity, urine CO_2, plasma CO_2, and plasma total base concentration. The measurements pertaining to acid-base balance will be presented in a subsequent publication.

All measurements were made daily except plasma volume and thiocyanate space. These were measured about every other day.

EXPERIMENTAL RESULTS

Examination of Figure 5 and Table I, II, and III show that the subject was in good salt balance during the preliminary control period; plasma chloride concentration varied ±2%, urine chloride ±6; total extracellular salt estimations were 103 and 101 Gm.

TABLE II.— *Experiment W. L.—Chloride Measurement*

Experimental Period	Day of Experiment	Plasma Chloride Concentration (mEq/L)	Plasma Chloride Concentration (mg% NaCl)	Plasma Chloride Concentration % Control	*Total Plasma NaCl Content (Gm./NaCl)	†Total Thiocyanate Space NaCl Content (Gm./NaCl)	Urine NaCl Concentration (Gm./L)	Urine NaCl % Control Concentration
Control	1	106.0	620	ave. =		102.9	3.7	ave. =
	2	102.4	599	100%	—	—	3.3	100%
	3	103.8	607		15.5	101.0	3.5	
Depletion	4	103.4	605	100.0	—	—	2.0	57
	5	97.6	571	94.2	14.0	86.2	0	0
	6	88.6	518	85.5	11.0	73.0	0	0
	7	81.2	475	78.4	—	—	0	0
Replacement	8	78.4	459	75.7	9.0	69.8	0	0
	9	80.4	470	77.6	—	—	0	0
	10	86.2	509	83.2	12.5	73.8	0	0
	11	89.6	524	86.5	—	—	0	0
	12	93.6	548	90.3	15.6	—	0	0
	13	98.0	573	94.6	—	—	0.3	0.7
	14	101.6	594	98.1	—	120.6	1.0	27
	15	107.0	626	103.3	—	—	2.1	60
	16	107.4	628	103.7	23.2	130.6	—	—

* Total plasma salt content = plasma NaCl concentration × plasma volume

† Total thiocyanate salt content = plasma NaCl concentration × thiocyanate space volume.

During the four days of gastric suction there was a daily negative salt balance of —12.4 Gm., —13.7 Gm., —5.9 Gm., and —2.8 Gm.; a total of 34.8 Gm. of salt loss in four days. Salt replacement was completed on the sixth day of the replacement period, 33.2 Gm. NaCl having been replaced at the end of the fifth day and a total of 43.1 Gm. by the end of the sixth. The positive salt balance during the final three days represents a retention in excess of that lost during the depletion period.

During the first day of gastric suction, extracellular salt content decreased 15 Gm., a loss equal to the total amount of salt normally present in this subject's plasma. Despite this salt depletion, plasma chloride concentration fell

only 6%, while on the other hand, urine chloride concentration fell to zero and remained zero. These figures show that the moderately severe salt depletion was quickly apparent from the decrease in urine chloride concentration while it was scarcely detectable from the plasma chloride concentration determinations. The plasma chloride concentration was being maintained by cessation of chloride excretion in the urine.

At the end of the depletion period, plasma chloride concentration was 459 mg. %, a fall of only 24% below normal control concentration. At this time the extracellular salt content had fallen 32 Gm. below normal, this figure checking well with the 34.8 Gm. of NaCl recovered from the gastric fluid and

TABLE III.—*Experiment W. L.—Miscellaneous Data*

Experimental Period	Day of Experiment	Body Weight (Kg.)	Spun Hematocrit, Percent	Total Blood Loss by Venapuncture (cc.)	Total Plasma Protein (Gm. %) Gm./cc.	Plasma Volume (cc.)	Thiocyanate Space (cc.)	Urine Sp. Gr.
Control	1	63.20	45.0	50	6.29	—	16,600	1.009
	2	62.50	48.5	62	6.69	—	—	1.004
	3	63.15	45.4	112	6.29	2,560	16.600	1.020
Depletion	4	53.00	44.5	124	6.30	—	—	1.014
	5	59.10	48.0	174	7.35	2,460	15,100	1.031
	6	57.50	51.4	224	—	2,120	—	1.027
	7	57.10	54.1	236	8.60	—	—	1.022
Replacement	8	56.55	52.5	286	7.26	1,950	15,200	1.019
	9	57.40	—	298	7.36	—	—	1.009
	10	58.90	41.7	348	6.65	2,460	14,500	1.007
	11	58.20	41.8	360	6.28	—	—	1.008
	12	59.40	39.4	410	6.22	2,850	9,800	1.007
	13	59.75	37.8	422	5.74	—	—	1.013
	14	60.45	33.6	472	5.03	—	20,300	1.008
	15	61.00	34.0	484	5.03	—	—	1.008
	16	61.50	33.4	534	5.03	3,700	20,800	—

NB—The following daily observations will also be reported in a future publication; Plasma CO_2, plasma total base, urine pH and urine CO_2

urine, and corresponding to one-third of the normal extracellular salt content, and twice the normal plasma salt content. This fall in plasma chloride concentration indicated a serious alteration in extracellular isotonicity. Clinically, the subject was lethargic, fainted on rising from bed, his eyes appeared sunken, the skin became loose and dry and scaley. Despite this extreme water and salt depletion, the plasma chloride concentration never fell as low as had the urine chloride concentration during even the first day of depletion.

The fall in urine volume to a minimum of 425 cc. per day would be expected in this state of "mixed" water and salt depletion. Reduction in both urine volume and urine chloride concentration indicate a mixed depletion requiring both salt and water therapy.

During the third part of this experiment, water was restored by free oral intake while salt restoration was accomplished by a low salt diet supplemented

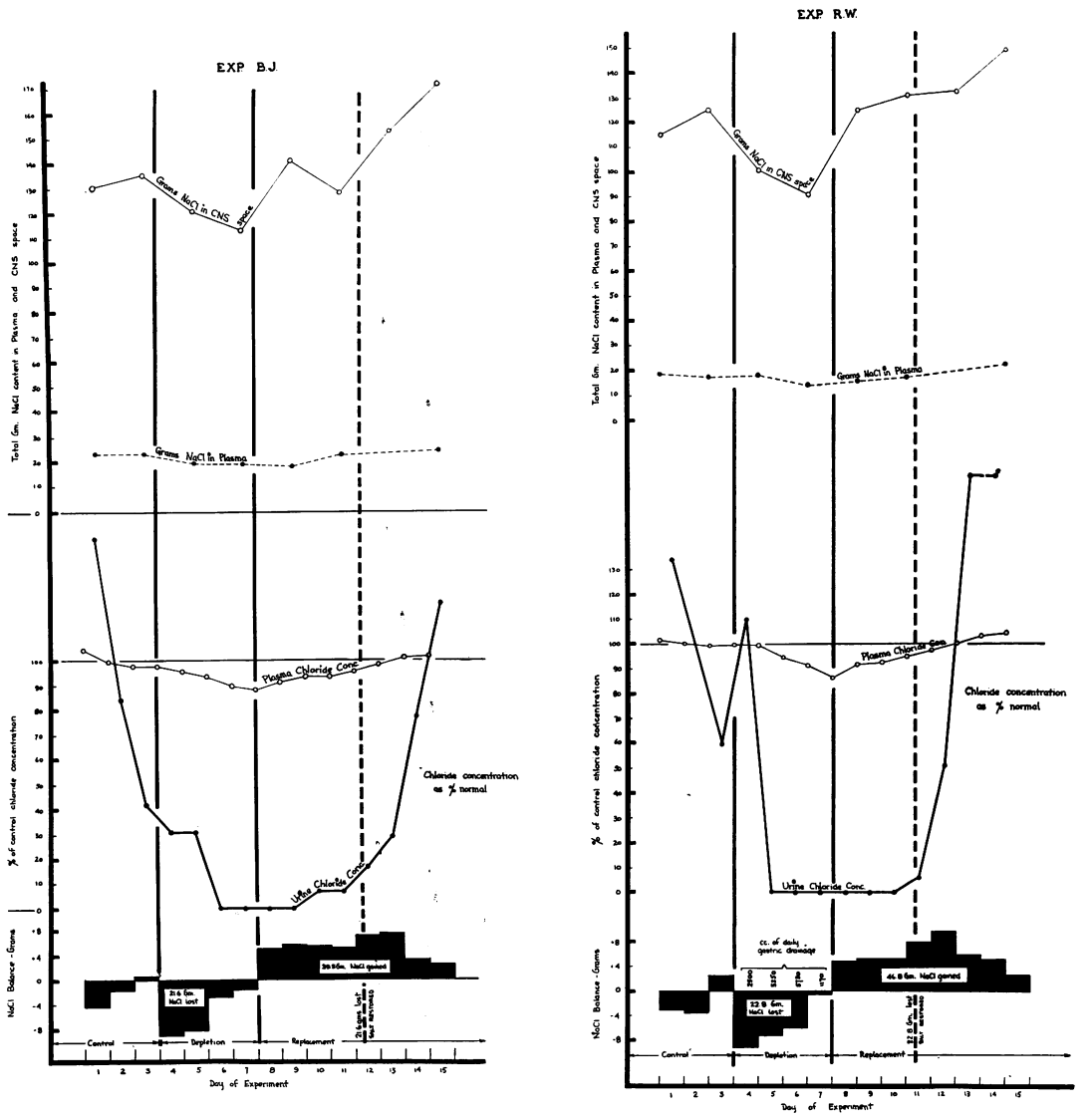


FIG. 6.—Showing experiments identical to that of Figure 5. The results are confirmatory.

by intravenous 0.9% saline. Salt replacement was completed during the early part of the sixth day. At this time (see vertical broken line on Fig. 5) the extracellular and plasma salt contents had returned to normal, chloride reappeared in the urine, but plasma chloride concentration had returned to only about 95% normal. Continuation of daily infusions of 1000 cc. 0.9% saline during the final four days caused a rapid increase in extracellular salt content and urine chloride concentration, and by the time plasma chloride concentration returned to normal, the total number of grams of salt in the extracellular fluid was 120% of the amount observed in the preliminary control period.* That this actually represents a subclinical edema is confirmed by the hematocrit and total protein concentrations; both fell to 20% below normal (corrected for experimental red blood cell and protein loss). Apparently urine chloride concentration better indicated salt replacement than did plasma chloride concentration; for chloride reappeared in the urine as soon as the 34.8 Gm. body salt deficiency was replaced, while return of plasma chloride concentration to normal was accompanied by overloading of the extracellular space with salt and water.

This experiment indicates a renal threshold level of about 95% normal plasma chloride concentration. Below this concentration chloride did not appear in the urine. It supports the physiologic hypothesis presented earlier in this paper and demonstrates the advantages of urinary over plasma chloride analysis.

Figure 6 represents similar studies carried out on the two other volunteer subjects. The results are similar to those discussed above. There was a renal threshold level of about 95% normal plasma chloride concentration. Below this level, chloride did not appear in the urine. The urine chloride concentration was a much more sensitive indicator of salt depletion and replacement than was the plasma chloride concentration. Continuation of saline infusions after chloride appeared in the urine caused excess salt and water to be retained in the extracellular space.

DISCUSSION

A slight discrepancy between the experimental observations published here and those reported earlier from this laboratory[10] is to be noted. It was observed in dogs that "When a condition of salt depletion is being established, drop of chloride excretion to a low rate is a more sensitive indicator of the condition than is the plasma chloride concentration. But when the condition of depletion of the type caused by loss of gastric juice is in process of correction by NaCl administration, restoration of normal plasma chloride concen-

* The changing thiocyanate space volume in this experiment is not a cumulative technical error resulting from accumulation of repeated thiocyanate dosage. This was proven by repeating the series of thiocyanate determinations in this same subject while in a normal state six months after the experimental period. Thiocyanate space measurements every other day for two weeks gave the following volumes: 15.5L, 15.0L, 18.2L, 17.9L, 17.3L, 16.3L, 17.4L, 17.9L.

tration shows more accurately than resumption of chloride excretion when enough saline has been given to correct the condition." During salt replacement there was a lowered renal chloride threshold in the dog experiments, but this was not observed in the experiments on man.

This discrepancy is best explained by the great difference in experimental conditions. In the dog experiment reported, salt replacement was conducted rapidly, i.e., 1 Gm. NaCl per pound body weight during 12 hours, and there was a diuresis of the accompanying dextrose and water infused. A single massive intravenous infusion was given. Salt replacement in the human experiment was accomplished slowly over five to six days, no rapid infusions were given, nor was diuresis stimulated.

The present work does confirm the previous observations[10] that an internal alkalosis resulting from hypochloremia may be accompanied by the excretion of an acid urine. Such a paradoxical concurrence was invariably present in the present experiment. Measurements of urinary pH, urinary CO_2, plasma CO_2, and plasma total base concentration of this and other subjects will be reported in the future.

CONCLUSIONS

There is sufficient evidence both in the literature (11, 12, 13, 14, 15, 16) and in our experiments on human volunteers to justify suggesting that, providing kidney and adrenal function are normal, *water and salt balance will be properly maintained if daily urine volume exceeds 1500 cc. and urine salt concentration approximates 3 Gm. per liter.* Since urine volume and approximate salt concentration are simple bedside determinations, they have been found very useful as routine guides to parenteral water and salt administration. It is fortunate that these guides are at the same time most informative and simple to determine, and are thus admirably adapted to clinical use.

There is a discrepancy between the above conclusions and the data presented in Figure 5. Figure 5 shows that chloride reappears in the urine as soon as salt restoration is complete (vertical broken line) and that increasing urine salt concentration is accompanied by excessive water and salt retention. This observation is confirmed in the other experimental subjects. Despite this experimental observation, it is recommended that salt balance will be best maintained if urine salt concentration is maintained at about 3 Gm. NaCl per liter. Limited clinical observations suggest that salt deficiency is apt to occur if one attempts to keep urine salt concentration slightly above zero; it has been easier and safer to maintain about 3 Gm. per liter urinary salt. Clinical studies of Bartlett et al[11] are in agreement with the experimental findings presented here. They recommended that, when their "volume for volume" rule cannot be followed, urinary chloride excretion be maintained at one or less grams per day, although such procedure may result in slight chloride depletion and fall in plasma chloride concentration. On the other hand, Hadden[12, 15] recommends that saline infusions be given until the urine contains 5-10 Gm. of NaCl in 24 hours. Sauchez-Vegas and Collins[14] agree with Hadden. Those recommending minimum urinary salt excretion do so in

fear of salt retention, while those recommending relatively great salt excretion fear salt depletion. A compromise seems advisable and agrees with the recommendation that urinary salt concentration be kept at about 3 Gm. per liter and urinary output at about 1500 cc. per day. Further clinical observations will decide whether these recommendations are optimum.

Urine salt concentration rather than daily salt excretion is recommended with the realization that the latter is probably a more accurate guide to salt administration. However, the determination of daily salt excretion necessitates the inconvenience of measuring the salt concentration of aliquot samples of twenty-four-hour urine collections. Furthermore, it is convenient to measure the urine salt concentration at the bedside just before starting each infusion, and to administer dextrose solution if there is more than 3 Gm. of salt per liter of urine, or saline solution if there is less than 3 Gm. per liter.

It is also suggested that urine salt concentration determination may be used to detect the presence or absence of body salt depletion. If the Fantus test is used and one drop of silver nitrate turns the urine-potassium chromate mixture red, one may assume that salt depletion is present; and, conversely, when there are at least 3 Gm. of salt per liter of urine, saline therapy is rarely indicated.

Thus the information obtained from urine NaCl concentration measurement at the bedside or in the emergency room is valuable in deciding whether or not the patient needs salt therapy, while measurement of urine volume excretion is valuable in deciding whether or not the patient needs water therapy. We must not place complete dependence on these simple measurements as quantitative guides to such a complicated physiological mechanism as water and salt equilibrium. These guides must be supplemented by clinical observations of edema, skin turgor, thirst, respiration, the appearance of the tongue and eyeballs, mental state, etc.

It is not suggested that plasma chloride determinations be discarded. As salt depletion progresses, salt first disappears from the urine and then plasma chloride concentration continues to fall. Once the urine has become salt free, plasma chloride concentration must be determined in order to estimate the magnitude of salt depletion. If plasma chloride concentration is abnormally low, plasma CO_2 concentration must be measured.

In the presence of decreased kidney function it is probably safer to depend on plasma chloride than on urine salt measurements; poorly functioning kidneys may fail readily to excrete salt. There is evidence indicating that renal function may be depressed in conditions causing diminished blood volume, as in dehydration, during and immediately following shock, and immediately postoperatively. Further studies are needed before urinary salt determinations can be recommended in these conditions.

At present there is discussion in the literature concerning the concentration of saline to be infused intravenously. Further discussion is intentionally avoided here, for it is the purpose of this paper to separate dehydration into two categories, water depletion and salt depletion, and to recommend that

each type of depletion be treated separately. Discussion of electrotlytes other than NaCl is also avoided in this paper, although it is understood that simple NaCl therapy is frequently incomplete electrolyte therapy.

SUMMARY

It is suggested that the loose term "dehydration" be substituted by its physiologic components: "primary water depletion," "primary salt depletion," and "mixed water and salt depletion." The physiologic basis for this recommendation is presented as well as the reasons for using urine salt (measured as chloride) concentration and urine volume instead of plasma chloride concentration as a guide to the diagnosis and treatment of these various types of dehydration. An experimental study of volunteer subjects is presented in support of this recommendation.

BIBLIOGRAPHY

[1] Fantus, J. B.: Fluid postoperatively. J.A.M.A., **107**: 14, 1936.

[2] Gamble, James L.: Extracellular Fluid. A Lecture Syllabus. Cambridge, Harvard University Press, 1947.

[3] Peters, John P.: Body Water; The Exchange of Fluids in Man. Springfield, Charles C. Thomas Publishers, 1935.

[4] Marriott, H. L.: Water and Salt Depletion. Brit. M. J., **1**: 245, 285, 328, 1947.

[5] Coller, F. A., V. Lob, H. H. Vaughan, N. B. Kalder, and C. A. Moyer; Translocation of Fluid Produced by the Intravenous Administration of Isotonic Salt Solutions in Man Postoperatively. Ann. Surg., **122**: 663, 1945.

[6] Moyer, C. A., M. Levin, F. W. Klinge: The Volume and Composition of Parenterial Fluids and Clinical Problems of Body Fluid Equilibrium. South. M. J., **40**: 479, 1947.

[7] Van Slyke, D. D., and J. Sendroy, Jr.: The Determination of Chloride In Blood and Tissues. J. Biol. Chem., **58**: 523, 1923-1924.

[8] Gregersen, M. J., and J. D. Stewart: Simultaneous Determination of the Plasma Volume With T-1824 and the "Available Fluid" Volume With Sodium Thiocyanate. Am. J. Physiol., **125**: 142, 1939.

[9] Phillips, R. A., et al: Copper Sulfate Method for Measuring Specific Gravities of Whole Blood and Plasma. New York, Josiah Macy, Jr. Foundation, 1945.

[10] Van Slyke, K. K., and E. I. Evans: The Paradox of Aciduria in the Presence of Alkalosis Caused by Hypochloremia. Ann. Surg., **126**: 545, 1947.

[11] Bartlett, R. M., D. L. C. Bingham, S. Pedersen: Salt Balance in Surgical Patients. Surgery, **4**: 441, 1938.

[12] Haden, R. L.: Treatment of the Toxemia of Obstruction of the Gastrointestinal Tract. Surgical Clinics of North America, Cleveland Clinic Number, 1399, 1937.

[13] Orr, T. G., and R. L. Haden: Chloride Treatment of Intestinal Obstruction. South, M. J., **19**: 300, 1926.

[14] Sanchez-Vegas, J., E. N. Collins: Importance of Urinary Chloride Determinations in Treatment of Patients Having Pyloric Obstruction. A Review of 50 Cases of Duodenal Ulcer. Am. J. M. Sc., **211**: 428, 1946.

[15] Haden, R. L.: Preparation of Patients for Operation on the Upper Gastrointestinal Tract. Surgical Clinics of North America, Cleveland Clinic Number, 1465, 1941.

[16] Benedict, F. G.: A Study of Prolonged Fasting. Carnegie Institute of Washington, **203**: 268, 1915.

DISCUSSION.—DR. I. S. RAVDIN, Philadelphia: These studies represent the type of work which is necessary to provide a clearer knowledge of the fluid and electrolyte requirements of surgical patients. In adopting Marriott's classification which divides dehydration into two conditions that differ in cause in physiologic and chemical effects,