Staff Meeting Bulletin
Hospitals of the » » »
University of Minnesota

Use of Fluids in Pediatrics

Volume XI | Friday, February 16, 1940 | Number 17

STAFF MEETING BULLETIN
HOSPITALS OF THE . . .
UNIVERSITY OF MINNESOTA

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INDEX

Published for the General Staff Meeting each week
during the school year, October to May, inclusive.

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William A. O'Brien, M.D.

I. LAST WEEK

Date: February 9, 1940

Place: Recreation Room
Powell Hall

Time: 12:15 to 1:00 p.m.

Program: Movie: "Donald's Cousin Gus"

Mycosis (Granuloma) Fungoides
Harry A. Cummings
J. F. Wilson
Discussion
J. F. Wilson
K. W. Stenstrom
F. W. Lynch

Present: 147

Motion Pictures (Fluoroscopic Images)
L. G. Rigler

Gertrude Gunn
Record Librarian

- - -

II. MOVIE

Title: "Inside Nazi Germany"

Released by: March of Time Series

- - -

III. ANNOUNCEMENTS

1. CENTER FOR CONTINUATION STUDY

Proctology - February 12 - 17.
Diagnostic Roentgenology - February 12 - 17.
Otolaryngology - February 19 - 24.
Monday - Dr. Jackson
Tuesday - Dr. Lierle
Thursday - Dr. Meltzer
Dr. Shambaugh
Friday - Dr. Meltzer
Dr. Furstenberg
Dr. Shambaugh

Joint meeting with Minnesota Academy of Ophthalmology and Otolaryngology, Friday, 6:30 p.m., Minneapolis Club. Speakers: Drs. Furstenberg and Meltzer. Other teachers at course will be Drs. New, Phelps, Connor, Bryant, Williams, Lillie, Hochfilzer, Camp, Stenstrom, Fjelstad, Boies, Simonton, Newhart, Knight, Waldron, Bryngelson, and Miss Lindquist. The movies of Drs. Jackson and Joel J. Pressman and the Bell Telephone Company will be shown. There will be a free afternoon on Wednesday to visit Twin City points of interest. A registration of 70 otolaryngologists is anticipated.

2. LOTUS D. COFFMAN MEMORIAL SILVER SERVICE

Formal acceptance of this gift from physicians who have attended courses at the Center for Continuation Study will be made on Monday, February 19 at 4:00 p.m. The service will also be used that day for the first time. It was the ophthalmologists and otolaryngologists who started the fund two years ago. Prime movers were among others, Edward S. Murphy, of Missoula, Montana; and Roll O. Grigsby of Ashland, Wisconsin. This group left a voluntary offering to start the idea. It was carried to each new group with the result that $300 was collected in a short time. Mr. Johns Hopkins (relative of the founder of the famous school), who has been acting as the University's agent in connection with interior design and furnishings of new buildings was given the commission to purchase the silver set. He found six pieces -- a modern tray, a coffee urn of the Georgian period, and four pieces of 1803 Early American solid silver: tea pot, creamer, sugar, and waste bowl. The original price was considerably in excess of the amount which had been collected, but through elimination of the dealer's profit it was possible to make the purchase. Because of the extreme rarity of the American pieces, their value is now reported as considerably higher than the purchase price. The building will also be given a framed honor roll of those who contributed. Tea time at the Center for the medical and hospital courses has now become an institution. P.S. The coffee urn is much larger than the tea pot. The cook finds in it an outlet for her artistic ability (arranging sandwiches and cakes), and the entire Center staff participates in the affair. Physicians' wives and other women visitors preside at the table. The registrants report that this daily break for refreshments enables them to put in fresh hours before dinner....

IV. THE USE OF FLUIDS IN PEDIATRICS

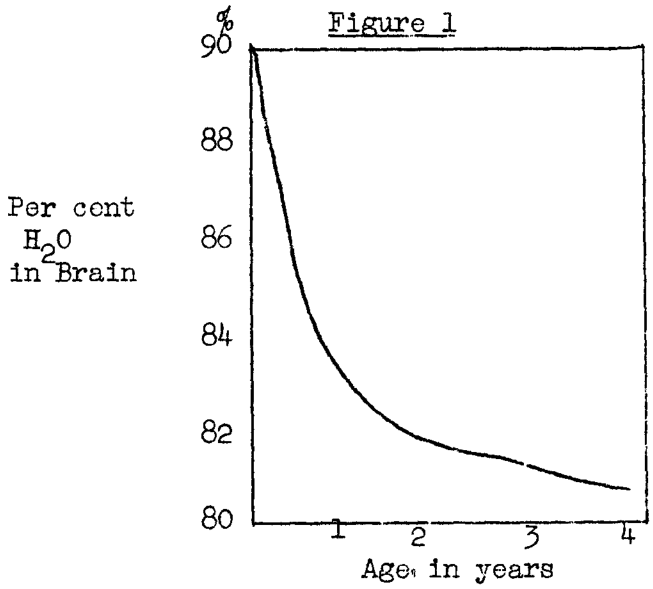
John A. Anderson
Mildred R. Ziegler

Because of the many important roles played by water, stability of the fluid matrix of the body is now recognized as the first pre-requisite to sound health. This stability or "steady state" of the body is maintained normally by many factors. The most important of these is the joint action of the autonomic nervous system, and the various hormones or "chemical regulators" which control the circulatory, respiratory, secretory, and excretory organs.

In order to obtain a rational therapeutic approach to the many clinical problems involving disturbances in water and mineral metabolism, it is necessary to use constantly our knowledge of the physiological mechanisms concerned in this control, and of the physico-chemical forces immediately responsible for the translocation of water and solutes within the body.

This problem is of particular importance in the field of pediatrics because of the greater susceptibility to the deleterious effects of changes in the volume and composition of the body water, which are so commonly associated with states of diarrhea, vomiting, fever, and infection. This in part may be explained by the greater per cent of water in the body of infants and children as compared with adults. At six weeks the human embryo is 97.5% water, at birth 72% water. The values for adults have been given as 68% - 70%. The brain has 89% water at birth and 81% at 4 years of age. (Fig. 1)

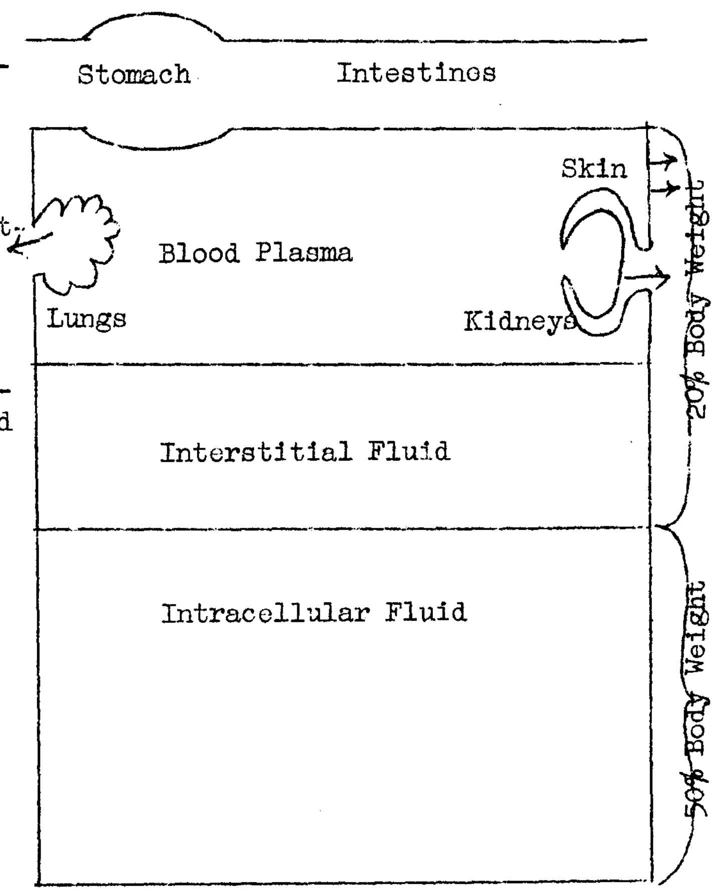
Figure 1



From a practical point of view, it is convenient to consider the water content of the body as divided into several compartments. These are distinguished not only by their situations within or outside of the body cells, or closed vessels, but by their composition as well. (Figure 2.)

Figure 2

The Water Compartments of the Body (Gamble)



By injection methods with sucrose, thiocyanate, bromide, and sulfate it has been found that the extra-cellular compartment is equal to approximately 20% of the body weight. By analysis, as well as by injection of thiourea, the total body water is approximately 70% of the body weight. Thus the mass of water in the various compartments is as follows: Extra-cellular 20% of body weight, Intra-cellular 50% of body weight, and water of vascular tree is approximately 5% to 6% of total body water.

This subdivision of the extra-cellular compartment into the vascular and interstitial compartments is justified by virtue of the fact that the capillary walls, while freely permeable to all crystalloids and inorganic ions, are relatively impermeable to the plasma colloids; that is, protein and lipids. The interstitial fluid outside of the vascular system is, therefore, an ultra filtrate of blood plasma. The volume of this compartment fluctuates freely in response to the quantity of fluid ingested or lost from the body and so serves as a buffer reservoir to preserve the relative constancy in the volume of the blood on the one hand, and the intra-cellular compartment on the other. Cannon compares it to a swamp which may be drained during periods of draught and inundated during periods of flood.

The factors regulating the exchange of water between the intra-cellular and extra-cellular compartments have not been extensively studied, but certain facts are known which are of utmost importance to the organism. The one force which is universally active in the exchange of water and electrolytes across the membranes separating these compartments is the osmotic pressure. The capillary walls while freely permeable to all crystalloids and inorganic ions are relatively impermeable to plasma colloids; that is, protein and lipids. In keeping with Donnan's equation, osmotic equilibria between the fluids on the two sides of interposed membranes are maintained by constant transfer of water from the side of lower to the side of higher osmotic pressure as changes in the composition of fluids require.

These alterations in the fluid composition are continuously occurring as a result of metabolic changes within the cells or as a result of absorption or excretion of various solutes. Thus the total osmolar concentration tends to be more or less uniform throughout the body fluids, in spite of the restraining membranes which prevent free diffusion of colloids and at some points, inorganic bases as well.

However, for an accurate understanding of these mechanisms of fluid exchange, one must have constantly in mind not only the space relationships of these compartments, but also the concentrations and types of ions which occupy these spaces. These differences in content, as has been mentioned, are due to an inherent ability of the separating membranes to discriminate against certain electrolytes. Thus the plasma water and the interstitial fluid contain chiefly sodium and chloride, whereas, the base of the cellular water (muscle) is chiefly potassium.

Figure 3

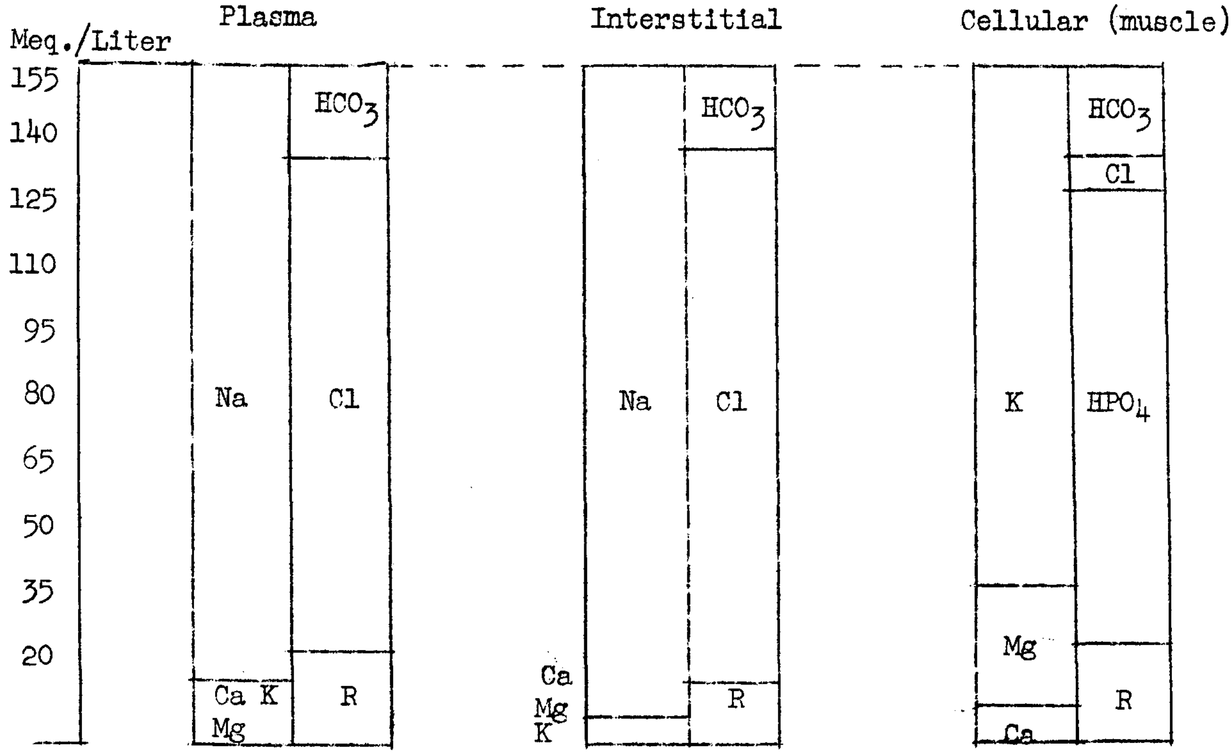


Figure 4

Electrolyte Composition of Blood Plasma

Base	Meq. per liter
Na	142
K	5
Ca	5
Mg	3
	155

Acid	Meq. per liter
HCO_3'	27
Cl	103
HPO_4	2
SO_4	1
Org. Acids	6
Protein	16
	155

Electrolyte Composition of Interstitial Fluid

Base	Meq. per liter
Na	145
Ca	4
K	4
Mg	2
	155

Acid	Meq. per liter
HCO_3	24
Cl	119
HPO_4	2
SO_4	1
Org. Acids	6
Protein	3
	155

Electrolyte Composition of Muscle Fluid

Base	Meq. per liter
K	120
Mg	27
Ca	8
	155

Acid	Meq. per liter
HCO_3'	24
Cl	5
HPO_4''	100
SO_4	4
Protein	22
	155

Under the normal physiologic processes the concentrations of these substances are held with absolute integrity, even though considerable changes in the volume relationships may occur. The volume relationships of the compartments has been said to be dependent on the concentration of sodium. Peters states that the concentration of sodium is more closely guarded than is the volume of water. There is a small amount of reserve base which can be readily called upon during periods of stress. This is soon depleted and thus not only the total concentration of electrolytes, or the total volume of fluid may change, but also the relative amounts of acid radicals as compared with basic radicals may change and a condition of alkalosis or acidosis may occur. It is during these states the emergent and proper therapeutics are necessary for the restoration of metabolic integrity of tissues.

It is not possible to mention all the clinical conditions in pediatrics which may be complicated by hydration changes; only those most commonly seen and of greatest importance will be discussed.

DEHYDRATION

Some degree of dehydration is very commonly seen in infants and children admitted to a pediatric service. Refusal of fluid and food with the onset of acute infectious diseases is common. Failure to supply an adequate water intake to newborn infants and even to older children invariably results in dehydration with fever.

Clinical picture of dehydration

Clinically this picture is recognized by characteristic changes. The child appears "tosic." He is at first restless, irritable, tosses head from side to side, occasionally utters a sharp high pitched cry and may draw legs up as if in pain. Later apathy, and a semi-stuporous condition with eyes rolled up under half closed lids occurs.

The skin is an ashen grey color, dry to touch, and parchmentlike, has lost its turgor, so that it may be pinched up in ridges which slowly flatten out when released.

In early states of dehydration thirst is excessive. Later, however, thirst is absent and offered water is vomited. This picture varies more or less with the degree of malnutrition which becomes increasingly more marked the longer that essential food stuffs and fluid are restricted.

Physiology of dehydration

The physiologic effects of dehydration are, (1) loss of weight, due initially to diminution in the interstitial volume, which contributes its water to the vascular and probably intra-cellular compartments in an attempt to maintain circulating volume, and adequate hydration of cells for proper metabolic activity. This loss is chiefly sodium and chloride and the dehydration does not reflect itself in significant changes in the circulatory fluid. When the dehydration is more extensive, tissue breakdown occurs in the effort to provide water for the maintenance of a normal content of circulating fluid. Fat and carbohydrate are first drawn upon for this purpose and later protein. There is a disturbance in the acid-base balance usually toward the acid side. Anhydremia is then present and due to decreased circulatory flow, metabolite retention occurs. Ketosis may exist early dependent upon the degree of malnutrition.

The so-called dehydration fever so commonly seen in pediatrics is explained as a decrease in the ability of the body to dissipate heat through radiation, because of the blood concentration and decrease in circulating volume.

Because the interstitial space is the reservoir for supply of fluid to the plasma, determinations of the hemoglobin, serum protein, hematocrit or plasma volume, reflect primarily the changes in the circulating volume of fluid, and not the degree of dehydration of the interstitial space. This is demonstrated by the draining of pancreatic juice by means of a fistula from a dog fed on a sodium free diet. Dehydration was progressive for ten days before any change occurred in plasma protein which is taken as an index of change in blood volume. (Figure 5).

Figure 5

Effects of Continued Loss of Pancreatic Juice

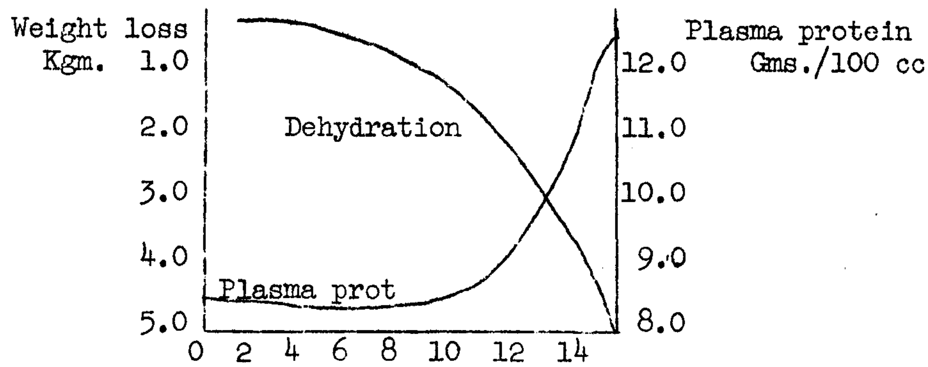
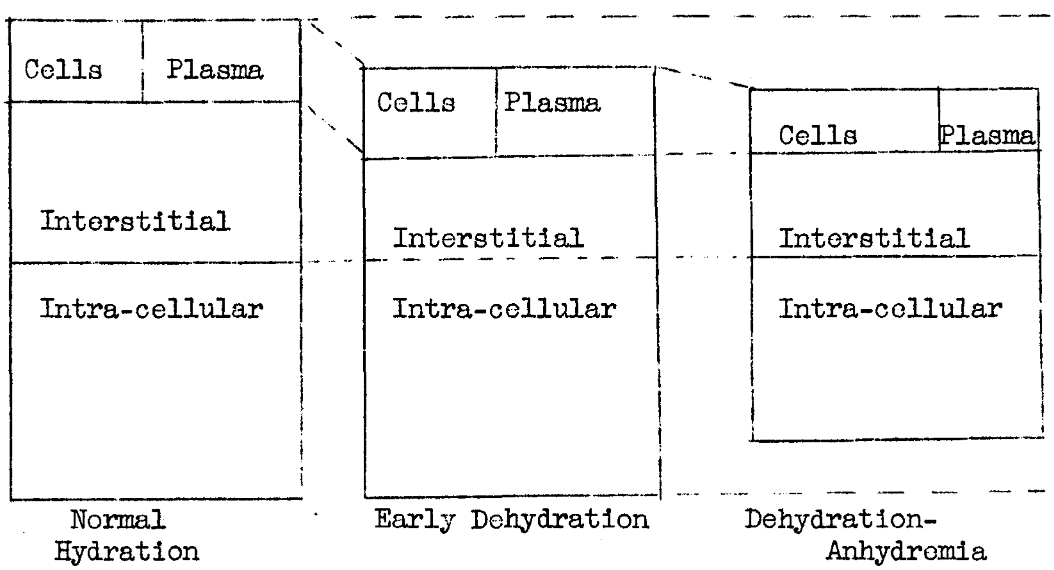


Figure 6 demonstrates diagrammatically the initial decrease in the interstitial space without change in the volume of Red Blood cells. Later when the interstitial space is exhausted, the circulating volume decrease is reflected by change in the hematocrit.

Figure 6



FEVER AND INFECTIONS

The relationship of states of hydration to infections, quite apart from that involved in heat loss by vaporization of water during fever, is very important. Barbour and Underhill have shown that the blood tends to become concentrated early in the course of febrile illness. Later the volume of blood is increased (hydremia). This effect is due in the main to the shift of water from the tissues to the vessels, though there is some evidence that the body's total content of water is increased, i.e., water retention occurs. During the course of fever the urine volume is markedly reduced, but the water excretion is increased above normal with the fall in temperature. Sandelowsky was the first to study the blood concentration salt balance, and weight changes in patients with pneumonia. In seven of his eleven patients the body weight either remained stationary or increased during febrile period, but fell rapidly after crisis. The four remaining cases showed a pre-critical loss of weight. These results have been confirmed by Welch and Drake, Suderman and Austin for pneumonia. While the evidence for water shifting due to infections is more spectacular in pneumonia, Rachman, Longcope, and Peters have demonstrated this reaction to be common for most febrile illnesses. Our knowledge of the susceptability of infection in hydro labile infants suggests that the most favorable state of hydration for resistance to acute infection may be one of mild dehydration.

Quite characteristically the onset of a febrile illness in small children and infants is accompanied by vomiting or followed by diarrhea. One must not lose sight of the fact that even though experimental evidence suggests water retention with febrile illness, any loss of acid or alkaline radicals is prone to precipitate some degree of alkalosis or acidosis, and thus a true dehydration on the basis of loss of sodium.

As a rule a number of factors are responsible for the development of acidosis in severe acute infections, the most important of which are:

(1) Toxemia leading to tissue injury and altered metabolism, and particularly to liver damage with resultant ketosis.

(2) Dehydration and oliguria from increased vaporization of water from lungs and skin, diminished fluid intake, or vomiting and diarrhea.

(3) Circulatory failure.

(4) Starvation ketosis.

<u>Volume of Extra-cellular fluids in various disease conditions</u>

Dr. Theodore Papermaster has used the intravenous injection of a known quantity of NaSCN into several children suffering from various clinical conditions in an attempt to measure the influence of various diseases on the volume of extra-cellular fluid. These values are given in Figure 7.

Figure 7

Volume of Extra-cellular fluids in various disease conditions.

Case	Sex	Condition	Age	Wt. Kg.	Extra-cellular H_2O in % of Body Wt.	Hematocrit %
G.A.	F	Psychiatric	14	75	22.6	40
J.C.	M	Zeroderma Pigm.	13	33.7	28.2	44
A.B.	M	Pubertas Praecox	8	39.4	22.9	46
H.P.	F	Ascaris Infection	12	35.	28.5	39
B.W.	F	Cong.Lues.	13	44	24.6	38
E.W.	M	Psychiatric	12	38	26.4	38
D.N.	F	Normal	14	51	24.9	44
L.H.	F	Diabetic Acidosis	14	39	19.8	43
		After 4000 cc. of fluid			21.6	43
		After diabetic adjustment			25.5	41
V.S.	F	Nephritis	12	35	30.7	38
D.S.	M	Nephritis	6	20.8	42.3	29
V.D.	M	Chron.Nephritis	15	60.9	26	27
I.K.	F	Cardiac	22Mo	10.4	51.4	42
J.N.	M	Undulent Fever	12	37.6	29.2	43
J.F.	M	Pneumonia	4	15	35.6	35
D.W.	M	Pneumonia	6	17.2	34.9	40
D.D.	M	Chron.Encephalitis	17Mo	7.2	32.2	39
C.W.	M	Fever Undiagnosed	12	32	29.3	39
M.C.	F	Lymph.Leukemia	9	25.5	35.4	32
F.M.	F	Vomit.Dehydration	3	11.8	21.	42

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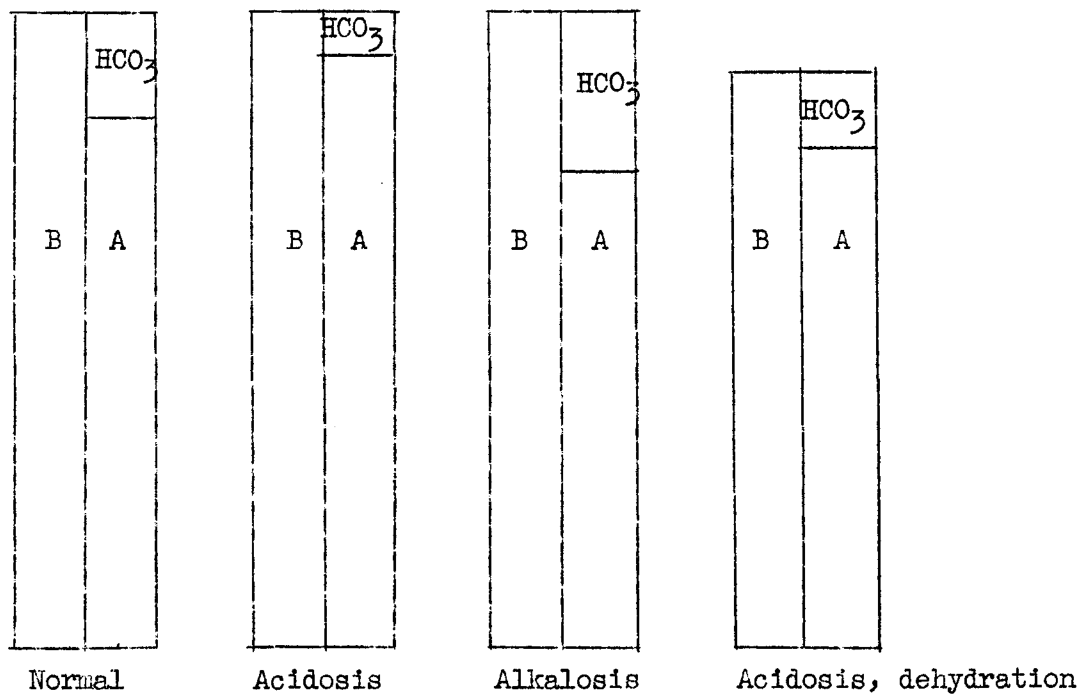
ACIDOSIS AND ALKALOSIS

From the preceding discussion, stability of the fluid matrix of the body is dependent upon constancy of the concentration of the substances in solution in this volume of fluid. Of further importance is, of course, the relationship of the acid and base portions of these substances. Any change of one factor (acid) over the other (base) results in a compensatory mechanism, by the respiratory functions in an attempt to maintain this stability of fluid volume. When the condition progresses and the respiratory mechanism is inadequate to compensate for the defect, the kidney then attempts by its selective function, to maintain some degree of compensation.

The following chart (Figure 8) illustrates that a change of the plasma bicarbonate is not to be regarded as a plasma defect, but as an important adjustment in defense of a reaction made necessary by an underlying disturbance of the electrolyte structure.

Figure 8

Illustrating Adjustability of the Plasma Bicarbonate

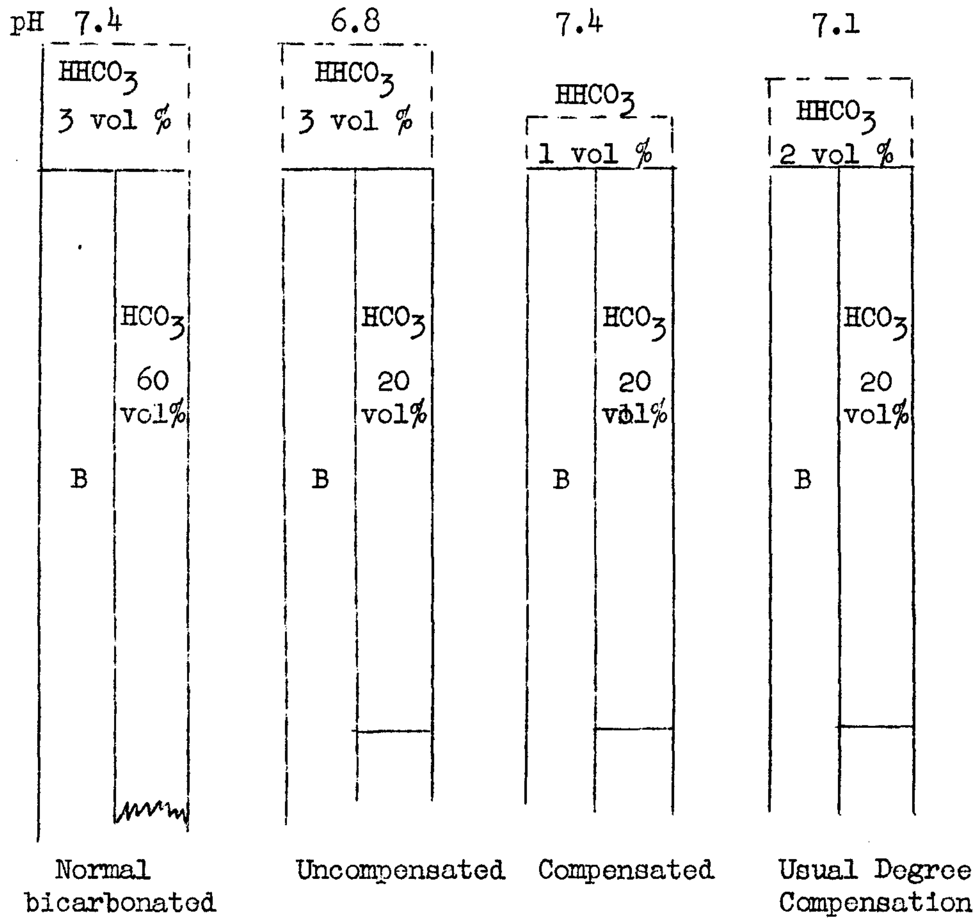


These large changes in the plasma bicarbonate shown in the preceding chart will obviously alter the normal free carbonic acid: bicarbonate ratio and cause extensive change in plasma pH unless the respiratory mechanism accomplishes an accurately corresponding change in the concentration of free carbonic acid.

Figure 9 illustrates in terms of H_2CO_3 : $BHCO_3$ ratio the change in plasma pH which could be caused by a reduction of the plasma bicarbonate to 1/3 of its usual value.

Figure 9

Compensating Change in Plasma Carbonic Acid Concentration Accompanying Reduction in Plasma Bicarbonate



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For complete compensation, a reduction of $HHCO_3$ from 3 volume % to 1 volume % would be necessary. This would demand a 3 fold increase in volume of residual air in the lungs, obviously an enormous demand on the ventilating capacity of the respiratory system.

The various disease conditions which may cause distortions of the normal electrolyte pattern of the plasma and make necessary compensating change in the bicarbonate concentration, have been outlined by Hartman. (Figure 10.)

Figure 10

Clinical Classification of Cases of Acidosis and Alkalosis

ACIDOSIS

A. Metabolic (Acid accumulation or alkali loss)
   1. Diarrhea and vomiting
      a. Nonspecific diarrhea
      b. Bacillary dysentery
      c. Intestinal obstruction and fistula
   2. Diabetes mellitus
   3. Nephritis
      a. Acute hemorrhagic (glomerular)
      b. Acute suppurative ("pyelitis") and acute toxic
      c. Chronic with renal destruction
   4. Severe acute infection
      a. Pneumonia
      b. Sepsis
   5. Miscellaneous
      a. Nondiabetic ketosis
      b. Convulsions
      c. Congenital heart disease
      d. Rheumatic heart disease
      e. Acid administration
      f. Exercise
      g. Dehydration
      h. Sulfanilamide

B. Respiratory (CO_2 excess)
   1. Exhaustion
   2. Paralysis of respiratory muscles
   3. Emphysema
   4. Toxins

ALKALOSIS

A. Metabolic (Alkali accumulation or acid loss)
   1. Obstructive vomiting
      a. Pyloric stenosis
      b. Intestinal obstruction and fistula
   2. Non-Obstructive vomiting
   3. Alkali administration
      a. Accidental
      b. Intentional
   4. Miscellaneous

B. Respiratory (CO_2 deficit)
   1. Encephalitis
   2. Hysteria
   3. Certain respiratory stimulants
   4. O_2 lack

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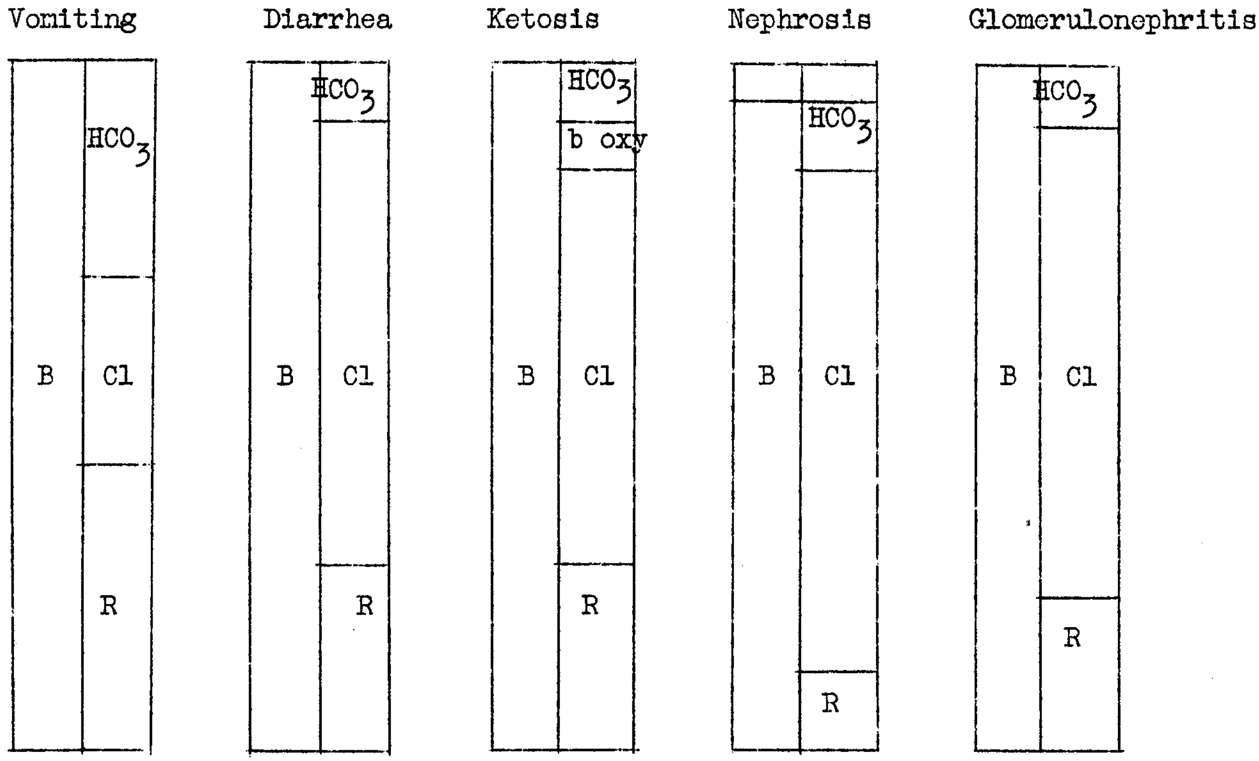
Of these numerous conditions, the three most common causes will be discussed.

1. Renal Disease. Since, with the exception of protein and bicarbonate ion, the normal values for the plasma electrolytes rest on renal control, disease of the kidney results, as would be expected, in the development of various defects in the plasma structure.

2. Disturbances of gastro-intestinal function when of sufficient degree to cause a loss of gastro-intestinal secretions by vomiting or diarrhea result in the withdrawal of electrolytes from the plasma.

3. Ketosis. The various conditions which lower the level of carbohydrate metabolism below the value required to cover the metabolism of the fatty acids make necessary the transport in the plasma of incompletely oxidized fatty acids en route for removal in the urine. An additional and abnormal factor must, therefore, be made place for in the electrolyte structure of the plasma. Figure 11 illustrates these conditions.

Figure 11



The influence of the loss of gastro-intestinal secretions by either vomiting or diarrhea is evident when one is aware of the volume and composition of these secretions. These are shown in Figure 12.

Figure 12

Total volume of digestive secretions produced in 24 hours by adult of average size.

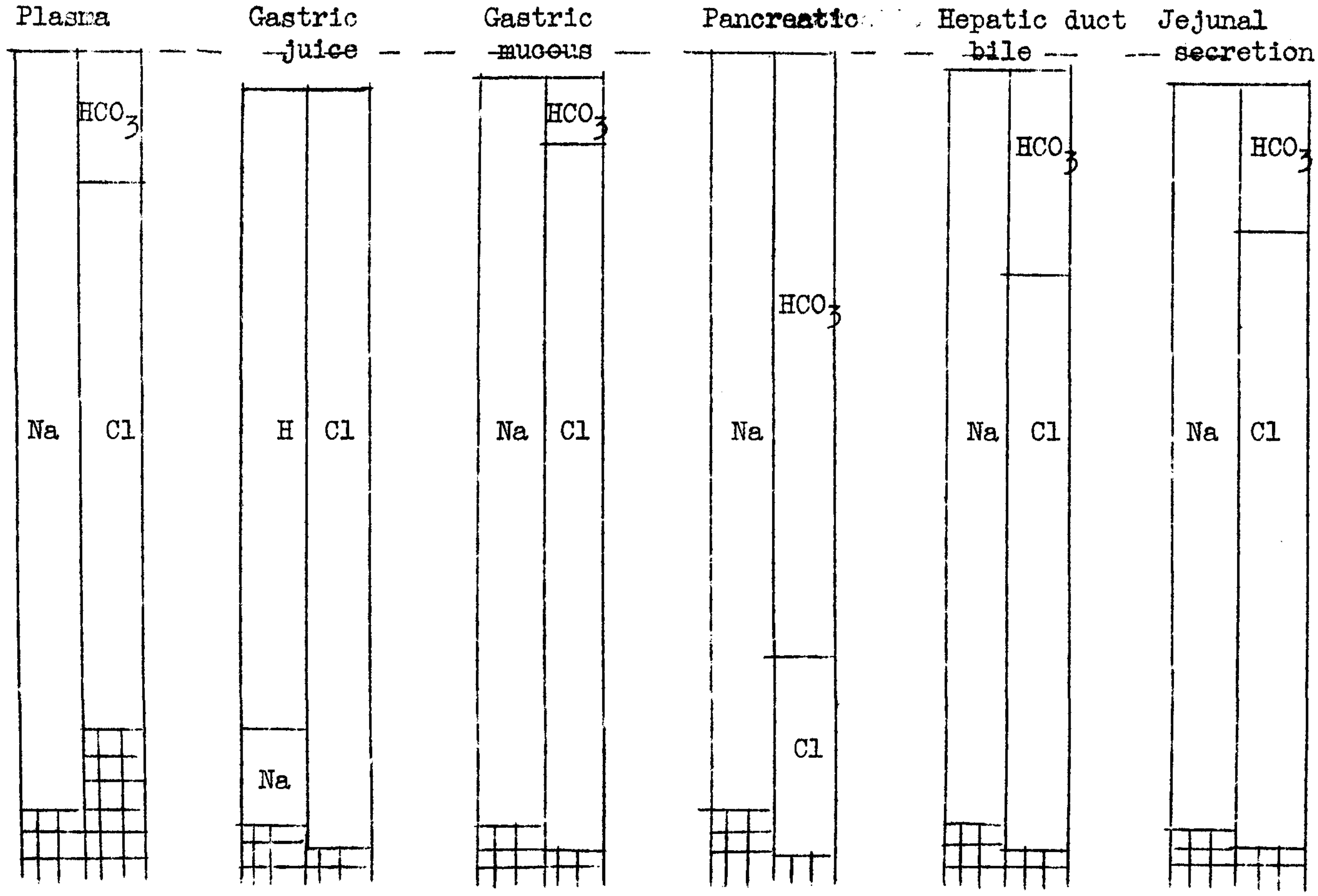
Saliva	1500 cc
Gastric secretions	2500 cc
Bile	500 cc
Pancreatic juice	700 cc
Secretion of intestinal Mucosa	3000 cc
	8200 cc

Blood plasma volume -- 3500 cc.

In Figure 13 depicting the composition of these secretions, it will be seen that loss of gastric juice results in a larger withdrawal of chloride ion from the plasma than sodium, whereas, loss of pancreatic and jejunal juice will withdraw sodium much more extensively than chloride. The total quantity of electrolyte in the secretions, as shown by the heights of the diagrams, is closely the same as in blood plasma.

Figure 13

The Electrolyte Composition of the Gastrointestinal Secretions



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It is obvious that for an accurate therapeutic approach to the problems of dehydration and acidosis or alkalosis, the determination of the complete electrolyte patterns of the blood is impractical. However, the measurements which will give us accurate information of the condition that underlies the change in the bicarbonate, are: total base, CO_2 content, and the chloride of the plasma. These values will tell us (a) the severity of the condition that is producing the change in the bicarbonate, (b) its corresponding effect upon the chloride, (c) and the extent of depletion of the extra-vascular compartment from the depletion of total base.

Clinical symptoms of Alkalosis and Acidosis

From our knowledge of the composition of the gastric intestinal secretions, it can be seen that accurate history is of prime importance. When the picture of vomiting is predominant - alkalosis will be suggested, and when diarrhea is outstanding acidosis will occur. The presence of both tends to offset the effect of each other, but acidosis usually predominates inasmuch as there is also metabolic acidosis present with the dehydration.

Alkalosis

In alkalosis there are usually enough important clinical symptoms which warrant taking of blood sample for CO_2 content. Respiration is affected in such a way that CO_2 tends to accumulate in the blood and prevent the decrease in H^+ ion concentration, (rise in pH), which would otherwise follow upon the increase in bicarbonate. This compensatory breathing usually takes form of shallow slow respiration with prolonged periods of apnea, ordinarily associated with Cheyne-Stokes respiration. It is at times so shallow that it is difficult to determine if respiration is present. These infants are usually disturbed by pain and hunger, and crying may be common.

In spite of the prolonged apnea, moderate marked cyanosis is rare. This is perhaps explained by the greater tendency for oxyhemoglobin to retain its oxygen as a result of increased alkalinity. The urine is concentrated and acid, and contains a large amount of ammonia. Chloride is absent. Tetany may be present.

Acidosis

As in alkalosis, there are usually enough clinical findings in acidosis to warrant its suspicion and further investigation. The diagnosis is established with certainty only by finding of lowered serum carbon dioxide content.

The type of respiration is perhaps of most importance. In severe cases this is usually quite noticeably of the air-hunger type: deep, rapid, and painless. In weak, especially in premature or moribund infants, however, such air hunger may be absent because of respiratory failure. Of almost equal importance to respiration is the appearance of the skin. Because of dehydration, the skin is dry and inelastic and not uncommonly leathery. Its color tends to be grey because of construction of peripheral capillaries and poor circulation. Some degree of stupor is present. Urine is concentrated and strongly acid, and usually contains albumin and casts. Ketosis may exist and the odor detected in the breath. The urine is not characteristic.

Treatment of Dehydration

For the treatment of dehydration states, a knowledge of those values which compose the water balance of the body is necessary. In addition one can only approximate the influence of the various pathological states which will augment the normal losses of fluid. These, of course, are many, such as, fever, sweating, withdrawal of fluid from diet, by duodenal suction, vomiting, diarrhea, changes incident to operations, polyuria, etc.

The individual items entering into computation of the water exchanges of the body are depicted in the following chart. (Figure 14.)

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Figure 14

Water Balance of Body

Sources of Water	Disposition of Water
1. Water drunk (or injected)	1. Urinary loss
2. Preformed water of food	2. Fecal loss
3. From oxidations in tissues	3. Insensible loss from skin and lungs
4. From syntheses and polymerizations in tissues	4. Lost in sweat secretion
5. Released from destruction of body tissues	5. Deposited with new tissues

The average amount of water required by children at different ages under ordinary conditions is shown in Chart 15.

Figure 15

Table: Range of Average Water Requirement of Children at Different Ages Under Ordinary Conditions

Age	Average Body Weight in Kilos	Total Water in 24 Hours	Water per Kilo Body Weight in 24 Hours
3 days	3.0	240 - 300	80 - 100
10 days	3.2	400 - 480	125 - 150
3 months	5.4	750 - 864	140 - 160
6 months	7.3	950 - 1,130	130 - 155
9 months	8.6	1,075 - 1,240	125 - 145
1 year	9.5	1,140 - 1,300	120 - 135
2 years	11.8	1,350 - 1,475	115 - 125
4 years	16.2	1,600 - 1,800	100 - 110
6 years	20.0	1,800 - 2,000	90 - 100
10 years	28.7	2,000 - 2,440	70 - 85
14 years	45.0	2,250 - 2,700	50 - 60
18 years	54.0	2,160 - 2,700	40 - 50

Whatever the cause of dehydration, one is always met with the problem of deciding how severe is the dehydration and what volume and type of fluid shall be given to rehydrate the patient without producing cardiac or respiratory embarrassment. This is of prime importance particularly if emergent surgical procedures are contemplated. This judgment depends at present upon numerous things which are difficult to measure. The degree of toxemia, severity of infection, the degree of impaired kidney function, cardiac function and presence or absence of shock, and degree of acidosis or alkalosis present.

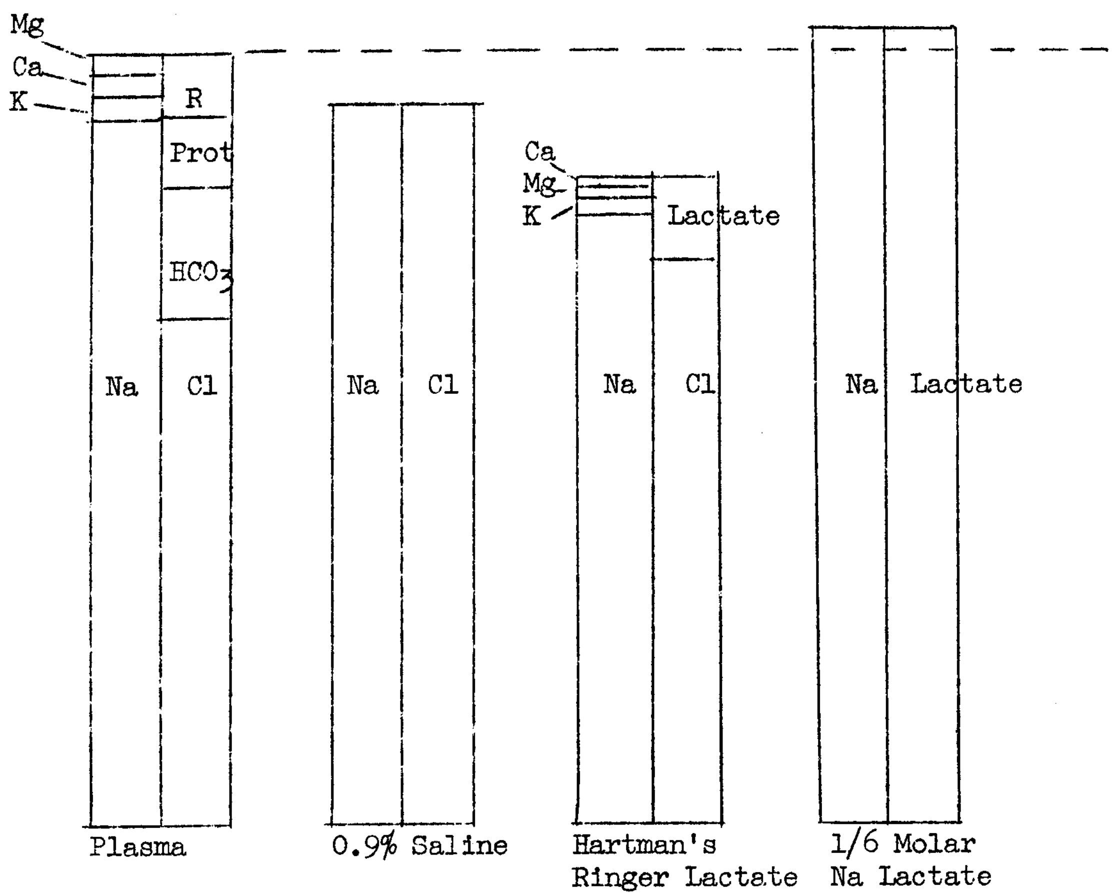
Determination of hemoglobin, hematocrit, serum protein, manifest increases only when the interstitial space has been greatly reduced in volume and a loss of water is now occurring from the circulating fluids. On the other hand, vascular shock may produce similar rises in these blood elements due to a transudation of water out of the vessels and into the interstitial space.

In order to accurately determine the extent of dehydration, the total amount of water in the body would have to be determined. This at present is impractical. We would also have to determine the volume of extra-cellular fluid and have some standards with which approximation of dehydration could be made. From what has been stated in regard to the purpose of the interstitial fluid, changes in this compartment may reflect to some extent changes in the volume of the total body water, and measures directed toward restoration of this compartment should be attempted first.

When it is impossible to meet these requirements orally or rectally repair solutions must be given by intravenous, subcutaneous or intra-peritoneal routes. In order to accomplish such a purpose without too much reliance upon the aid which renal activity may afford or upon the aid with which absorption of food from the intestinal tract may provide, it is necessary to give parenterally fluids which are quite similar to normal interstitial fluid, or at least to incorporate into such a solution the most essential mineral constituents of body fluids. Those most commonly used in this clinic and found to be the most satisfactory are shown in Figure 16.

Figure 16

Repair Solutions



The compositions of these fluids are as follows:

	0.9% NaCl	Hartman's Lactate Ringer's Solution	1/6 Molar Na-Lactate
mg per 100 cc.			
NaCl	900	600	
K Cl		40	
$CaCl_2 . 2 H_2O$		20	
$MgCl_2 . 6 H_2O$		20	
$Na H CO_3$			
$Na H_2PO_4 . 2 H_2O$			
Na-Lactate		305	2030
Osmolar Concentration	288	256	312

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A 6% dextrose solution is isotonic with blood, and is of course used to furnish nutrition as well as to prevent the formation of ketone bodies associated with the malnutrition. Sodium bicarbonate solution is of distinct value, but because of its difficulty in preparation it has not been used on our service.

Surgical Conditions.

The treatment of dehydration associated with operations in children is of particular importance. In such operations as herniotomy, appendectomy, plastic procedures, etc., where surgical trauma is slight, the chief effect upon the water balance is probably that of the anesthesia. The fluid requirements are probably not greatly in excess of the usual daily requirements as indicated in the chart. Gibson and Rourke state that with ether anesthesia there is a slight decrease in plasma volume, and an increase in the interstitial volume. There is no change in the serum protein, sodium, or chloride concentrations. The dehydration associated with prolonged operations is invariably severe. Maddock and Collër state that a 60 kgm adult demands approximately 7600 cc. of fluid in the 24 hours subsequent to a severe operation. In adult patients in whom dehydration is slight or absent 3500 cc per 24 hours is considered adequate. In children these values are of course much too high, and should be adjusted according to the body weight. Coller and Maddock have shown that the symptoms and clinical signs of dehydration occur when the patient has lost an amount of fluid equal to 6% of the body weight. This value then can be accepted as the amount that can be safely given immediately to rehydrate patient. The amount of additional fluids necessary depends on the minimal requirement of the child according to age and weight plus an estimated amount necessary dependent upon the existing condition which tends to increase water loss from the body.

Thus to establish hydration in children who are clinically dehydrated, the minimal amount of fluid to be given is as follows:

Body Weight	5 kgm	300 cc.
	10 kgm	600 cc.
	15 kgm	900 cc.
	20 kgm	1200 cc.
	25 kgm	1500 cc.
	30 kgm	2000 cc.

These amounts can be exceeded dependent upon the clinical estimation of the degree of dehydration.

From what has been said in regard to the composition of the body fluids, simple dehydration would best be relieved by administration of Ringer's solution, or Ringer Lactate. This provides all the essential products except protein necessary to maintain a normal volume of the body fluids. Sodium chloride, because sodium is the predominant base, in a 0.9% solution will next best meet this demand. Glucose in 5-6% solution is also advisable to prevent further ketosis by furnishing nutrient material for oxidation.

Rate of injection:

Subcutaneously: 60-80 cc. per Kilo per 24 hours can usually be given without distending the skin markedly.

Intravenously: Altschule, Rourke, and Gilligan have shown that in normal adults 5% glucose and 0.9% saline can be given at a rate of 15 cc. [redacted]. per minute without significantly affecting the blood pressure, velocity of blood flow, or blood volume. At a rate of 20-25 cc. [redacted]. per minute there was an increase in cardiac output, velocity of blood flow and blood volume. These changes occurred after 500 to 1500 cc. had been given, but would invariably return to normal after 15 minutes. With larger than 25 cc. [redacted]. per minute the increase in velocity of blood flow was less than expected from cardiac output. There was thought to be an increase in the pulmonary blood volume.

The rate for the intravenous administration of such fluids to infants and children should certainly not exceed the following:

Normal	5 - 10 cc. ~~per kgm~~ per minute
Dehydrated	10 - 15 cc. ~~per kgm~~ per minute
Debilitated -toxic or febrile	5 cc. ~~per kgm~~ per minute or less
Incipient shock	10 - 20 cc. ~~per kgm~~ per minute
After hydration	3 - 6 cc. per kgm per hour

In only exceptional circumstances should the volume given at this rate exceed that of 6% of the body weight. If continuous intravenous fluid therapy is given the rate should not exceed 3 - 6 cc. per kgm per hour after the establishment of hydration.

When specific neutralization therapy is indicated because of the loss of gastric or intestinal fluid, the proper fluid dependent upon diagnosis of condition should be given to adjust first, the acid-base imbalance and then the dehydration.

Treatment of Acidosis

Sodium lactate solution is indicated in specific amounts when severe acidosis of any type exists, other than that associated with congenital heart disease with persistent cyanosis. The amount to be given is calculated from the carbon dioxide content of the blood and the weight of the patient in the following manner. No. of cc. Molar Rocemic Na-Lactate equals (60 - CO_2 content) x .3 x Body Wt.
This quantity is then diluted with five volumes of distilled water. Usually one-half to two thirds of this volume is given intravenously at a rate not to exceed 25 cc. of solution per kgm per hour, and the remainder is given subcutaneously. This is followed by sodium chloride plus 6% glucose, or Hartman's Ringer lactate plus 6% glucose subcutaneously in an amount calculated from the age of the child to meet its minimal fluid requirements for the subsequent twenty-four hours. Additional amounts can be given depending upon clinical appearance of the child and the severity of the condition producing the dehydration and acidosis.

Acidosis of diarrhea

General outline of the treatment of severe diarrheal acidosis is as follows:

1. Total restriction of food.

2. Isotonic sodium racemic lactate in calculated dose from CO_2 content; or 10 cc. of molar solution per kgm body weight, one half intravenously, one half subcutaneously.

3. Hartman Ringer physiologic buffer solution parenterally.

4. Dextrose for fuel and to relieve ketosis in 3-6% solution subcutaneously at a rate of 3 to 4 cc. per kilogram per hour after dehydration is relieved.

5. Blood transfusion should always follow hydration and not before, as it intensifies anhydremia. Blood facilitates removal of edema which is common and favors excretion of fluid by kidneys.

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Case Report

Infant, age 2 months.

History: Fever-diarrhea - vomiting - two days duration. Apathy, rapid breathing, cyanosis - 8 hours duration.

Progress and treatment:

12/25/39

1. 10 P.M. Admission - CO_2 21 Vol.% Body weight 3500 gm.
2. 10 to 12 P.M. given 210 cc. of calculated 244 cc. of Racemic Sodium Lactate 1/6 molar. (60 - 21) .3 x 3.5 Kg x 6 equals 244 cc.
3. 12 P.M. to 6 A.M. 300 cc. NaCl subcutaneously. 120 cc. 1/6 molar lactate subcutaneously.

12/26/39

4. 9 A.M. CO_2 equals 56 vol. % B.U.N.

59.4 mgm%. Edema now present; Anuria present since admission.

5. 11 A.M. 75 cc. citrated blood intravenously.
6. 2 P.M. Voiding. Edema present.
7. 5 P.M. CO_2 72 Vol.%. 300 cc. $2\frac{1}{2}$% glucose subcutaneously, $\frac{1}{2}$ strength Hartman's Ringers by mouth. Myringotomy both ears revealed pus.

12/27/39

8. 9 A.M. CO_2 69 Vol. % B.U.N. 27.2 mgm%. Diarrhea stopped. Small feedings taken. Edema less.

12/28/39

9. 9 A.M. CO_2 69 Vol. % B.U.N. 15 mgm% Infant feeding well, temperature normal, diarrhea ceased.

Diabetic Acidosis

The customary routine for treatment of diabetic acidosis is as follows:

1. Insulin: 2 units per kg. body weight.
   $\frac{1}{2}$ intravenously,
   $\frac{1}{2}$ subcutaneously
2. Calculated amount of racemic sodium lactate is given intravenously as rapidly as possible. When CO_2 content is not known, 10 cc. of molar sodium lactate per kg. body weight is given.
3. Lactate Ringers or sodium chloride is then given in sufficient amounts to relieve any remaining dehydration. This usually amounts to 40 cc. per kg. body weight and can generally be given in a single subcutaneous injection.
4. Total amount of fluid necessary is usually 100 cc. per kg. body weight.
5. Six hours after initial injection of insulin, $\frac{1}{2}$ unit insulin per kg. body weight is given. Subsequent doses depend upon blood sugar and urine sugar and if the patient can be relied upon to take liquid nourishment or regular meals.
6. Satisfactory restoration of acid base equilibrium can be accomplished by this method usually within 6 - 12 hours after institution of treatment.

Case Report

Patient aged 14 years. Weight 39 kil[o]
History: Acetonuria, nausea, progressive coma past 48 hours. Cause, Acute Pharyngitis, Diabetes.

1/5/40

2 P.M. admitted CO_2 18 Vol.% Blood sugar 480 mgm%.

6 P.M. 2800 cc. 1/6 Molar Racemic Sodium Lactate plus 1000 cc. saline solution.

10 P.M. CO_2 content 72 Vol.% Blood sugar 266 mgm%.

1/6/40

7 A.M. CO_2 78 Vol.% blood sugar 105 mgms%. Patient feels wel[l] able to eat entire breakfast.

Acidosis of Nephritis

Acute hemorrhagic, toxic and suppurative nephritis.

In general the acidosis of acute nephritis is not important clinically, and usually improves with the restoration of diuresis or cessation of convulsions. The acidosis of suppurative nephritis usually responds to repeated injections of 1/6 molar racemic sodium lactate.

Chronic nephritis

The acidosis of chronic nephritis is related chiefly to defective kidney excretion of acid metabolites, and inability of kidney to produce ammonia. It will respond temporarily to sodium lactate, but the treatment is only palliative.

Treatment of Alkalosis and Dehydration

Two objectives:

1. The institution of measures which would relieve tetany or prevent its recurrence.
2. Restoration of the bicarbonate contents and pH of the body fluids .

together with restitution of the electrolyte balance in the broader sense, including water content. Tetany can be relieved by intravenous Ca Cl_2 $\frac{1}{4}$ cc. per kg. body weight of a 5% solution. Breathing 30% CO_2 and O_2 may be of value.

Two methods are used: the direct and the indirect.

Direct: Reduction of bicarbonate by intravenous HCL followed by Ringers solution.

Indirect: Requires administration of Ringers or Lactate Ringers for period of 48 hours or longer.

Inasmuch as the use of intravenos HCl demands accurate observation of the blood bicarbonate during treatment, it is not generally used.

The indirect treatment depends upon (1) restoration of fluid and total base, (2) excretion of excess base, administered as chloride, but excreted as bicarbonate until the chloride level has been completely reestablished. Further administration of saline would be attended by excretion of chloride in urine.

While lactate Ringers is not especially indicated in the relief of this type of alkalosis, in fact is slightly inferior to the use of Ringers solution alone, because of the tendency for slight increase in alkalosis until the total base concentration of the blood has been reestablished, it is quite effective and becomes superior to Ringers solution, later if following the operation for pyloricstenous, diarrhea develops and tends toward the production of acidosis. Since this indirect method for relief of alkalosis depends on <u>selective renal activity</u>, it is obvious that it will be ineffectual, if for any reason secretion of urine is interfered with. In this case edema usually results and no significant change in the degree of alkalosis will occur. The B.U.N. is elevated and uremia develops.

Transfusions should be given to elevate serum protein in the hope that kidney function may improve. It is in this case that direct neutralization with HCL would be of life saving value. It is wise to always give a transfusion just as soon as dehydration is relieved.

Duodenal Suction

Inasmuch as the gastric and duodenal secretions are so closely related to plasma in their concentration of base, it can be readily seen that continuous suction over several days is likely to deplete chloride to the extent of the production of an alkalosis. Its chief effect is to produce a dehydration to the extent of the volume of fluid removed. Baine and Armstrong have studied the chloride balance in these cases and conclude that the administration of 2000 cc. of normal saline solution daily will maintain a positive balance of chloride (excretion) and prevent any serious alkalosis. Replacement with saline or Ringer lactate solution in the quantity equal to that removed should supply adequate fluid and chloride to prevent alkalosis under these conditions.

Conclusions

Only by knowledge of those conditions which tend to produce dehydration in infants and children, and early recognition of the state of dehydration, can adequate prophylactic measures be instituted in order to prevent the serious metabolic disorders that follow loss of fluid from the body.

The active treatment of dehydration, and alkalosis and acidosis, demands <u>quantitative</u> knowledge of the extent of the disorder, and thus quantitative replacement of specific fluids necessary to restore the body water to normal relationship of volume and composition. This treatment should be an emergency, and should be continued as long as those factors which entered into the production of the disorder exist.

Outline of Treatment of Acidosis and Alkalosis

(I) Measures to Aid Respiratory Defense
- A. Respiratory Stimulants in the Extreme Type of Acidosis with Respiratory Failure.
- B. Avoidance of Respiratory Stimulants other than CO_2 - CO_2 Inhalations (for alkalosis)

(II) Measures to Restore Normal Buffer Values
- A. In Acidosis:

  Direct
  1. $NaHCO_3$
  2. Blood (for restoration of Hb and plasma protein)

  Indirect
  1. Na-lactate and other salts of organic acids (Na citrate (Na acetate - "Alkaline" ash diet ($CaCO_3$ ($SrCO_3$
  2. Glucose or glucose and insulin when ketosis exists
  3. O_2 when anoxemia exists due to pulmonary causes
  4. Fluids when anoxemia exists due to dehydration and anhydremia

- B. In Alkalosis:

Direct	Indirect
1. HCl	1. NH_4Cl
2. H_2CO_3 (CO_2)	2. $CaCl_2$
	3. NaCl

(III) Measures to Promote Renal Activity
- A. Diuretics
  1. H_2O - saline and dextrose solutions - plasma protein - acacia
- B. Material for Chemical Reactions
  1. NaCl - KCl - Lactate-Ringer's solution (NaCl, KCl, $CaCl_2$)

(IV) Measures to Relieve Primary Causes, such as Diarrhea, Vomiting, Infection, Etc.

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V. GOSSIP

The local showing of "Gone With the Wind" at the Orpheum Theatre on Hennepin Avenue may be the reason that Dutro's seafood house is so crowded these days. It is reliably reported by our New England friends that at last we have a place which ranks with those in the East. Modern methods of transporting sea foods apparently make the difference. The equipment has a distinct nautical air. Newcomers are self-conscious when the "bibs" are tied on. The unconventional appearance soon causes everyone to discard silverware and start using their fingers.... Eric Kent Clarke supplies the following and insists that it really happened: The presence of the Psychiatric Clinic for Children on sixth floor adjacent to the Interns' Quarters is exerting a positive influence on the development of poise and benevolence on the intern group. Recently a four-year-old, gazing intently at the memorial plaque, Del Robbia's "Madonna and Child," was overheard to comment to his mother while waiting in the lobby for admission, "Mother, is Heaven like this?" At that moment Dr. Bugbee emerged from the Interns' Quarters and stepped into the elevator. As the elevator descended the child again turned to the Mother and asked, "Mother, do you think that could be one of the angels?"...John Amberg, son of Superintendent and Mrs. Raymond M. Amberg, went home this week after a successful operation for orbital abscess, secondary to an infected sinus.....Speaking of operations, our poliomyelitis patient who has been in a respirator since last fall was successfully delivered of a female child by section. The child was apparently normal. Our head obstetrician is receiving the congratulations of his associates....Dr. Joseph G. Pollard of Hanover, New Hampshire, is spending his sabbatical leave at Minnesota studying our methods of teaching personal and public health in the Arts College and also our athletic injury program. Dr. Pollard is a former midwesterner (he hails from Nebraska). A columnist recently remarked that southerners come from states (Georgians, Texans, and so forth), while the rest of us come from regions....William T. Middlebrook and Malcolm M. Willey of the University administration are batching it because of the absence of their wives in Florida. The change of climate was recommended because of illness of the Middlebrook children. Both Mr. Middlebrook and Mr. Willey have been much in demand socially and have become the gay young blades. No pun intended although skating has been their favorite outdoor sport....During February, the Minnesota State Medical Association is sponsoring "appendicitis" as the study subject for the month. Next month the subject will be rheumatic fever. The special report on rheumatic fever by Dr. Hanson and Dr. Dwan will be the main contribution. There will also be reports on arthritis. These study packets are becoming popular as the subjects are more specific. The radio programs over stations WCCO, WLB, and KDAL (N.Y. chain) also coincide with the study subjects for the month, so that physicians may obtain both medical and lay approaches to the same subject. The plan of selecting a study subject for the month is said to have originated in Indiana. Our physician members of the association must write to the state association offices for their packets. Between three and four hundred physicians from outside the metropolitan centers are cooperating. This number represents approximately one-third of the entire group involved....The Center for Continuation Study is offering a course in the Treatment of Venereal Disease from April 1 to 6. It is being sponsored primarily for a group of physicians who are coming from North Dakota. Their expenses will be paid by their state health department and selection will be based on the number of cases of venereal reported by them to the state health department. State health officer of North Dakota, Dr. Maysil Williams, is the only woman health officer in the United States. Our cooperative ideas in carrying on courses in obstetrics, pediatrics, and now in venereal disease, came from her. Similar projects may be arranged for physicians from South Dakota. There are approximately 400 physicians in each state......