HEMODYNAMIC CHANGES IN SALT DEPLETION AND IN DEHYDRATION [1, 2]

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It has long been known that extensive loss of body fluid may adversely affect the circulation (1). The importance of loss of fluid in the production of "shock" following burns and trauma has frequently been emphasized. More recently, it has been recognized that the loss need not be external. Body fluid regularly accumulates in an injured region and is to a considerable extent made unavailable to the organism (2, 3). Treatment with parenteral saline solution may have a dramatic therapeutic effect in shock associated with such local segregation of fluid. On the basis of this and other experimental observations, attempts have been made to assign a primary rôle to salt and water depletion in the etiology of traumatic shock (4 to 6).

A more exact knowledge of the effects of salt and water depletion on the circulation of the untraumatized organism is required before this point of view can be accepted. It is not known whether the effects of such depletion on the circulation may not differ in some significant way from those which accompany traumatic "shock." The relative effects on the circulation of water depletion and of salt depletion require definition. For example, there is clinical and experimental evidence that loss of salt is more deleterious to the circulation than is loss of water (7, 8). Although both may cause the same degree of contraction in extracellular volume, the contraction of plasma volume is greater after salt depletion (9). However, plasma volume alone does not characterize the state of the circulation, and hence hemodynamic measurements are necessary. Quantitative studies of circulatory dynamics have rarely been made in salt and water depletion. The few reports available are of limited utility since the associated changes in the body fluids were not measured (10 to 12).

It is the purpose of the present study to correlate changes in the several compartments of the body fluid with the dynamic changes in the circulation following salt depletion and water depletion. Such a study should assist in defining the rôle of water and of salt loss in the pathogenesis of traumatic shock.

EXPERIMENTAL PROCEDURES

Fasting unanesthetized female dogs were used throughout.

Acute sodium chloride depletion was produced by the intraperitoneal injection of 100 to 150 ml. per kgm. of body weight of 5 per cent glucose solution followed by the withdrawal 4 or 5 hours later of an equal amount of peritoneal fluid containing salt (13). Preliminary studies had indicated that at this time the maximal amount of salt had diffused from the body into the peritoneal fluid.

Acute water depletion in excess of salt was produced by the intravenous injection of a solution containing 10 per cent urea and 5 per cent glucose. A copious diuresis occurred during the subsequent 7 or 8 hours.

Total balances of water and of chloride were measured at the end of each experiment. Water balance measurements were based upon changes in body weight after urine was withdrawn by catheterization, corrected for fluid administered, and for water and solids removed. Water of metabolism was ignored because of the short duration of the experiments (14).

Hemodynamic measurements were made before and after depletion in the following sequence: circulation time, cardiac output, and arterial pressure. Initially, about 10 ml. of blood were withdrawn before arterial pressure was measured; after this 25 ml. of arterial blood were obtained for chemical analysis.

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The effects of 4 or 5 hours of acute salt depletion were compared with those of 7 or 8 hours of acute water depletion. In this way approximately equal degrees of contraction of extracellular fluid were produced in both groups of animals.

In one experiment with salt depletion intermediate measurements of changes in body fluids and in circulatory dynamics were made at 40, 86, and 300 minutes. To determine the effect on the circulation of a large volume of fluid in the peritoneal cavity, 0.9 per cent NaCl solution in place of 5 per cent glucose was injected intraperitoneally in 2 control experiments.

METHODS

Hemodynamic measurements

Circulation time from forepaw to medulla was measured by the interval between the injection of 1 to 2 ml. of 0.1 per cent sodium cyanide solution into the arm vein and the first deep respiration.

Cardiac output measurements were based on the direct Fick principle (15). Output was calculated by dividing the rate of oxygen consumption by the difference in oxygen content between arterial blood and mixed venous blood from the right auricle. Rate of oxygen consumption was regularly measured just prior to the withdrawal of the mixed venous specimen, using a standard Benedict-Roth basal metabolism machine with a special mask which was sealed with grease to the muzzle of the dog. Mixed venous blood was obtained from the right auricle by means of a ureteral catheter passed through a 13-gauge needle inserted into the right external jugular vein. Occasionally, this sample was obtained by direct cardiac puncture. Arterial blood was sampled by direct femoral puncture immediately after the mixed venous sample was collected. It was found that the oxygen content of the arterial blood did not change during this brief interval. Oxygen content was determined by the method of Van Slyke and Neill (16). The error of this method is less than 1 per cent, that of the arterio-venous oxygen difference 3 to 5 per cent.

Cardiac index. This is the ratio of cardiac output to surface area. The surface area was calculated from the body weight in grams (W), and the length from nose to anus in centimeters (L) by means of the formula of Cowgill and Drabkin (17), which simplified can be written as:

$$\text{Surface area (cm.}^2\text{)} = 1.59\sqrt[3]{W^2L}$$

The cardiac index is more generally employed than the cardiac output since it corrects for the variation in the size of the animals.

Mean arterial pressure in the femoral artery was measured directly through a 19-gauge needle connected with a mercury manometer through citrate-filled pressure tubing.

Calculation of changes in the volume of intracellular fluid (ΔI), of extracellular fluid (ΔE), of plasma (ΔPV), and of circulating plasma protein (ΔCPP)

The changes in intracellular fluid volume (ΔI) were obtained by subtracting extracellular volume changes from those in total body water. The latter were calculated from changes in body weight. Changes in extracellular fluid volume (ΔE) were obtained from the changes in chloride concentration in serum water and the chloride balance, assuming the initial volume to equal 25 per cent of the body weight. These methods have been described in detail elsewhere (14). In those experiments in which sodium determinations were made, the changes in concentration of sodium in extracellular water paralleled those of chloride very closely. Under these same experimental procedures, changes in concentration of chloride in extracellular water were used, therefore, to indicate changes in tonicity of extracellular fluid.

The change in plasma volume ($\Delta PV = PV_2 - PV_1$) was calculated by the use of the relationship

$$\frac{PV_2}{PV_1} = \frac{(1 - HKT_2)}{(1 - Hkt_1)} \times \frac{Hb_1}{Hb_2}$$

where Hkt_1, Hkt_2, and Hb_1, Hb_2 are respectively the initial and the final values for the relative cell volume and for the hemoglobin concentration of anaerobically defibrinated arterial blood. The validity of the formula is based on the assumptions that no erythrocytes have been removed from or added to the circulating blood other than those withdrawn in blood samples, and that the arterial hemoglobin and relative cell volume represent the average of these values throughout the entire circulation.

An initial plasma volume (PV_1) of 5.5 per cent of body weight was assumed, based on other studies (18). Changes in this volume were calculated from the changes in the hemoglobin concentration and the relative cell volume of anaerobically defibrinated arterial blood. Hemoglobin content was determined in an Evelyn photoelectric colorimeter after dilution of the blood 1 : 500 with ammonia solution. The original curve was obtained with blood samples whose oxygen capacity had been gasometrically determined. Relative cell volume was measured on anaerobically defibrinated blood in Daland microhematocrit tubes (19).

The change in circulating plasma protein (ΔCPP) was calculated from the protein concentration of serum of arterial blood and from the change in plasma volume by the formula:

$$\Delta CPP = PV_2P_2 - PV_1P_1$$

where P_1 and P_2 represent initial and final concentrations of protein, PV_1 and PV_2 the initial and final plasma volumes.

Chemical methods for determination of serum and urine chloride, serum protein, and blood nonprotein nitrogen have been described elsewhere (20). Calculation of the concentration of water in serum was made from the total protein content (21).

TABLE I

Acute salt depletion

Analytical data, hemodynamic measurements, and changes in body fluids

Experiment	Time from start of experiment	Weight*	Intake	Output†				Serum		Blood		Circulation time	Mean arterial pressure	Oxygen		Cardiac index	Total peripheral resistance	Change in			
			Intraperitoneal	Peritoneal fluid‡		Vomitus		Cl	Total protein	Relative cell volume	Hemoglobin			Consumption	A-V difference			Total water	Extracellular fluid	Plasma volume	Circulating plasma protein
			H_2O§	Volume	Cl	Volume	Cl														
	hours	*kgm.*	*ml.*	*ml.*	*m.eq.*	*ml.*	*m.eq.*	*m.eq. per liter*	*grams per cent*	*per-centage of cells*	*grams per cent*	*seconds*	*mm. Hg*	*ml. per minute*	*volumes per cent*	*liters per minute per square meter*	*absolute units*‖	*liters*	*liters*	*ml.*	*grams*
55F	0	10.95						111.9	6.36	47.2	12.6	8	156	100	4.1	4.98	5.11				
	4.5	10.61	1650	1891	124	0	0	88.9	10.24	62.2	15.8	15	78	112	14.2	1.61	7.87	−0.34	−0.61	−295	− 6.8
55G	0	10.80						108.2	6.40	46.9	12.5	7	135	100	3.1	6.59	3.35				
	4.5	10.45	1650	1769**	113	45	6	83.0	11.02	69.1	17.2	14	83	91	13.1	1.41	9.63	−0.35	−0.55	−343	−10.4
72E	0	10.46						108.1	5.57	51.8	14.3	5	170	91	3.1	6.10	4.64				
	4.5	10.26	1550	1344	83	65	8	88.2	8.50	65.5	17.2	8	142	114	12.7	1.88	12.60	−0.20	−0.40	−233	− 3.0
72F	0	10.44						108.5	5.78	53.0	14.6	6	172	100	3.8	5.48	5.23				
	4.5	10.20	1550	1586**	100	55	6	84.1	10.17	72.7	18.0	11	132	112	12.6	1.77	12.27	−0.24	−0.47	−304	− 5.7
76A	0	9.07						105.0	5.40	36.2	9.6	7	157	101	4.3	5.47	5.33				
	4.5	8.62	1375	1329	111	15	2	91.0	8.14	55.2	13.3	11	97	93	12.7	1.70	10.60	−0.45	−0.80	−246	− 6.4
77A	0	6.88						108.3	5.17	44.5	12.0	6	152	73	5.0	4.05	8.34				
	4.5	6.72	1050	1066	77	32	4	88.4	7.66	61.0	14.6	10	102	69	11.2	1.72	13.20	−0.17	−0.47	−160	− 2.8
78A	0	10.28						107.0	6.03	41.4	10.6	6	157	93	5.6	3.53	7.80				
	4.5	10.14	1500	1516**	101	30	4	87.0	8.66	55.5	14.4	15	103	60	13.1	0.96	18.30	−0.14	−0.55	−250	− 6.8
72A††	0	9.48						106.1	5.37	49.4	14.2	7	164	102	3.6	6.43	4.64				
	0.6	10.71	1275	25	45§§	50	5	94.0	5.64	50.9	14.6	10	148	67	5.1	2.98	9.05	−0.05	−0.17	− 29	− 0.2
	1.2	10.63		25	22§§	0	0	92.5	6.47	61.6	15.8	8	140	68	9.1	1.71	14.90	−0.07	−0.19	−135	− 4.6
	5	9.36		1188	12	0	0	87.9	8.26	64.6	16.6	9	124	85	18.2	1.07	21.20	−0.08	−0.07	− 43	+ 2.8

* Weight at end of period corrected for solids lost in feces and red cells in blood taken for analysis.
† Output of urine not tabulated as the volume never exceeded 5 ml.
‡ Peritoneal fluid as tabulated includes the small amount of serum in blood drawn for analysis.
§ Given as 5 per cent glucose solution.
‖ Dynes per second per cm.^{5} expressed in thousands.
** Peritoneal fluid withdrawn in Experiments 55G, 72F, and 78A contained 1.4, 1.0, 1.4 grams of protein respectively.
†† Balance data are expressed per individual period rather than cumulatively.
§§ Glucose solution injected during first period and withdrawn in last; in first 2 periods Cl in peritoneal cavity calculated as if it were outside extracellular fluid.

In both tables time from start of experiment indicates end of period at which time serum analyses and hemodynamic measurements were made. In designation of experiment, number refers to individual dog, letter refers to successive experiments.

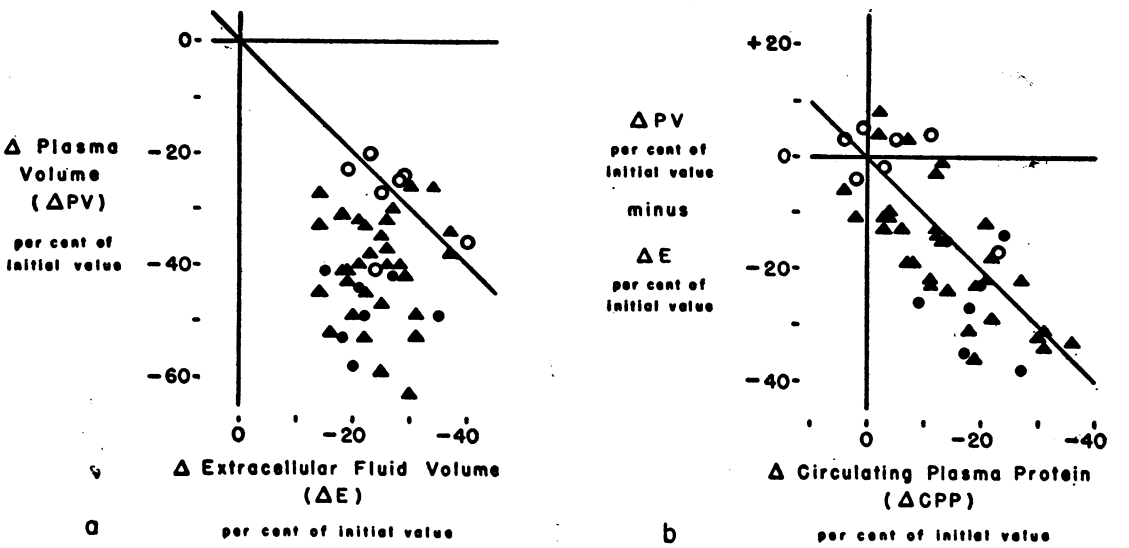

FIG. 1. COMPARISON OF (a) PERCENTILE CHANGES IN EXTRACELLULAR FLUID VOLUME WITH THOSE IN PLASMA VOLUME, AND (b) THE DIFFERENCE BETWEEN THESE 2 VALUES WITH THE PERCENTILE LOSS OF TOTAL CIRCULATING PLASMA PROTEIN

Open circles represent *water depletion.* Closed figures represent *salt depletion* (circles indicate experiments reported here, triangles indicate experiments reported elsewhere).

In water depletion, the fall in plasma volume is roughly proportional to the fall in extracellular fluid volume. In salt depletion, the decrease in plasma volume exceeds the decrease in volume of extracellular fluid (a). Disproportionate drops in plasma volume correlate well with loss of total circulating plasma protein (b).

RESULTS

Effects of acute sodium chloride depletion. The results of the 8 experiments in which initial measurements of the cardiac output were made are presented in Table I.[3] There are in addition 32 experiments with salt depletion which were similar in every respect to these 8 save for the omission of this initial cardiac output measurement. Data from some of these incomplete experiments are given in tabular form in the subsequent paper (22) and have been used along with the data of Table I in the construction of Figures 1 and 2.

Withdrawal of NaCl resulted in a large shift of water from the extracellular to the intracellular phase, with consequent depletion of the former and expansion of the latter. The body fluids became hypotonic. Plasma volume diminished greatly. In proportion to initial values, it usually contracted more than did the extracellular fluid as a whole (Figure 1a). Total circulating plasma protein was often lost in large amounts and was not recovered in the peritoneal fluid withdrawn. The circulation time increased markedly, and mean arterial blood pressure and cardiac output were greatly diminished (Figure 2). Since the percentage fall of mean arterial pressure was not

[3] *Values for normal cardiac output and cardiac index:* The mean value for cardiac index (cardiac output/surface area) obtained by us in 35 determinations in 19 normal unanesthetized dogs was 5.45 ± 1.43 liters per minute per square meter. In 25 determinations, the mixed venous blood was obtained by right auricular catheterization, in 10 by direct cardiac puncture. This value is among the higher values for the cardiac index of the normal unanesthetized dog collected from the literature by Wiggers (23). Since the values obtained by us for normal arteriovenous difference in oxygen content (mean 4.5 ± 1.3 volumes per cent) agree well, with few exceptions, with those found by other workers, the discrepancy must have been due to an unusually high rate of oxygen consumption by our dogs. This may be due to the fact that our dogs were not only unanesthetized but untrained. The incomplete mixing of the venous blood within the right auricle (24) also contributes to the uncertainty with which cardiac output can be determined by the direct Fick method. The expression of change in cardiac output or index in terms of percentage of initial value presents, therefore, some difficulty in interpretation, especially in those cases in which the initial value varies considerably from the mean.

as great as that of the cardiac output, the total peripheral resistance which is measured by this quotient (35) was increased in all the experiments.

The chief loss of NaCl and extracellular fluid, and the major drop in cardiac output occurred during the first 40 minutes. The plasma volume and the total amount of plasma protein declined most markedly later (Experiment 72A, Figure 3). Intraperitoneal injection of isotonic saline, in volumes equivalent to the glucose used in the salt depletion studies, did not significantly alter either the volume or the hemodynamics (data not given here). After withdrawal, a slight fall in cardiac output occurred.

Effects of acute water depletion (Table II, Figures 1 and 2). Body water was lost greatly in excess of chloride, and the remaining body fluids became hypertonic. The water lost was derived partly from the intracellular but mainly from the extracellular phase. With 1 exception, plasma volume diminished in proportion to the fall in extracellular volume. Total circulating plasma protein decreased significantly in only 2 experiments. Circulation time increased but slightly. Cardiac output fell markedly in 4 experiments and only moderately in 3. The mean arterial pressure fell somewhat in all but 1 experiment. Total peripheral resistance was usually increased.

Comparison of the 2 types of depletion. With

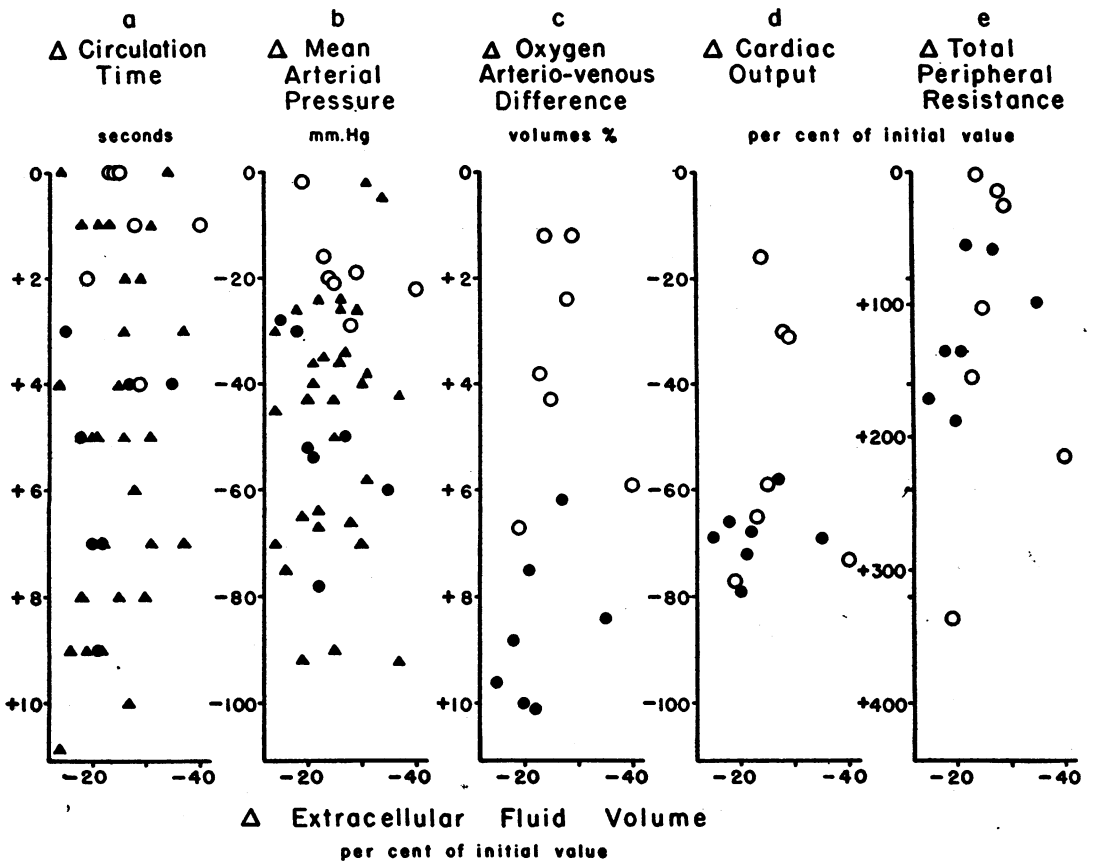

FIG. 2. COMPARISON OF HEMODYNAMIC CHANGES IN SALT DEPLETION WITH THOSE IN WATER DEPLETION

Percentile changes in extracellular fluid volume are plotted along the abscissae, the hemodynamic measurements are plotted along the ordinates. Symbols are interpreted in Figure 1.

Salt depletion in contrast to water depletion is characterized by a greater increase in circulation time, a greater fall in mean arterial pressure, and a greater rise in oxygen arteriovenous difference. There is no consistent difference between the 2 groups in the changes in cardiac output and in total peripheral resistance.

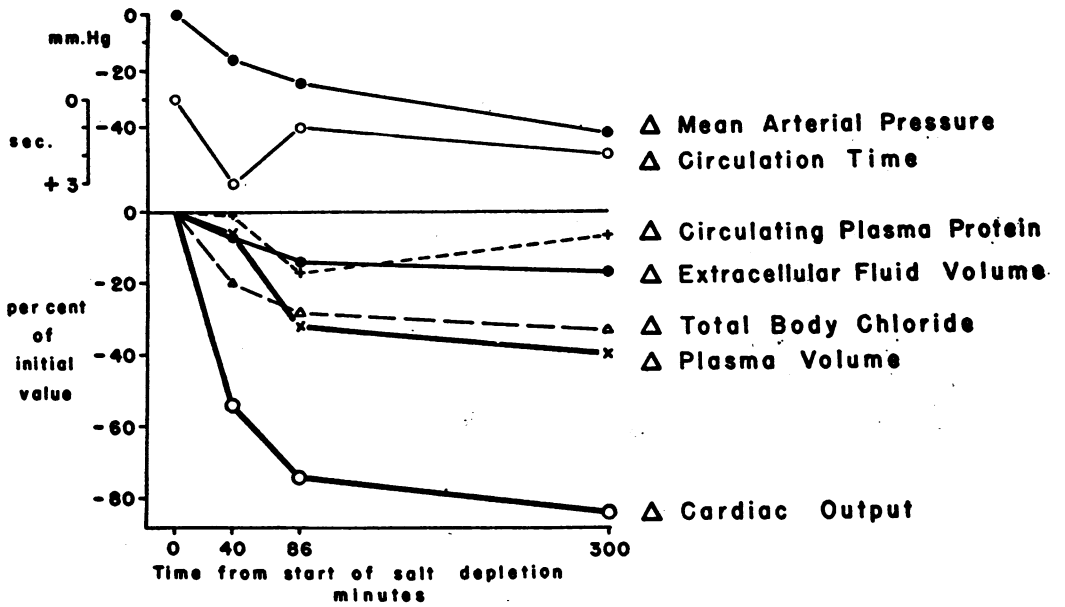

FIG. 3. RELATION OF CHANGES IN HEMODYNAMICS TO CHANGES IN BODY FLUIDS IMMEDIATELY FOLLOWING THE ONSET OF SALT DEPLETION (Experiment 72A)

At 40 minutes when the major loss of chloride has occurred, the main drop in cardiac output has taken place with relatively little change in plasma volume.

both procedures, there is diminution of extracellular fluid volume. Except in 1 case, the percentile decline in plasma volume with water depletion was proportional to that of the extracellular fluid; in four-fifths of the experiments with salt depletion, it was much greater (Figure 1a). The difference between ΔPV and ΔE (each calculated as percentage of its initial value) is, therefore, usually greater with salt depletion than with water depletion. The magnitude of this difference correlates well with the percentile change in total circulating protein, ΔCPP (Figure 1b).

Per unit change in extracellular fluid, the circulation time almost always rose less (Figure 2a) and the mean arterial pressure fell less (Figure 2b) in the water-depleted than in the salt-depleted animals. The increase in arteriovenous difference of oxygen content was less in all but 1 of the water depletion experiments (Figure 2c). The 2 groups of animals do not differ sharply with respect to the cardiac output (Figure 2d). All of the salt-depleted animals and 4 of the 7 water-depleted animals showed a marked drop. No consistent difference was found between the 2 groups in the increase of total peripheral resistance (Figure 2e).

In both types of depletion, the plasma volume and the cardiac output always changed in the same direction (Figure 4). In 5 of the water-depleted animals and in all of those depleted of salt, however, the correlation in magnitude was poor. With 3 exceptions, the fall in cardiac output, in proportion to its initial value, was much greater than that of the plasma volume.

DISCUSSION

"Shock" following trauma, hemorrhage, and extensive burns is characterized by a form of peripheral vascular collapse (2, 3, 26). Plasma volume decreases, protein is lost from the circulating plasma, venous return, cardiac output, blood presure, and circulation rate decline sharply (27). Identical changes occur in acute salt depletion. Insofar, therefore, as shock can be described in terms of these phenomena, salt depletion can produce shock.

Acute water depletion with a comparable decline in extracellular volume fails to reproduce this state of shock. Characteristically little protein is lost from the circulating plasma. Plasma volume merely drops in proportion to the extracellular fluid. In some respects, however, the

TABLE II

Acute water depletion

Analytical data, hemodynamic measurements, and changes in body fluids

Experiment	Time from start of experiment	Weight*	Intake	Output				Serum		Blood		Circulation time	Mean arterial pressure	Oxygen		Cardiac index	Total peripheral resistance	Change in			
			Intravenous	Serum for analysis		Urine		Cl	Total protein	Cell volume	Hemoglobin			Consumption	A-V difference			Total water	Extracellular fluid	Plasma volume	Circulating plasma protein
			H_2O†	Volume	Cl	Volume	Cl														
	hours	*kgm.*	*ml.*	*ml.*	*m.eq.*	*ml.*	*m.eq.*	*m.eq. per liter*	*grams per cent*	*percentage of cells*	*grams per cent*	*seconds*	*mm. Hg*	*ml. per minute*	*volumes per cent*	*liters per minute per square meter*	*absolute units*‖	*liters*	*liters*	*ml.*	*grams*
23S	0	9.94						106.4	7.14	33.6	8.7	8	130	102	7.0	3.17	7.12				
	8	8.99	600	27	3	1230	27.0	123.6	9.37	44.9	12.3	7	110	100	8.2	2.65	7.20	−0.95	−0.60	−226	−9.0
72B	0	9.38						103.6	5.93	40.3	11.7	6	153	87	3.5	5.66	4.91				
	8	8.50	538	27	3	1220	29.7	117.2	7.02	42.3	14.1	6	137	64	7.3	2.00	12.45	−0.88	−0.54	−103	−1.5
74A	0	9.85						105.0	6.53	40.6	10.8	8	147	89	7.3	2.65	9.64				
	7	8.75	600	30	3	1585	44.6	119.8	9.01	46.5	12.9	9	118	83	9.7	1.87	11.00	−1.10	−0.70	−133	+1.5
75A	0	12.39						105.0	5.76	46.4	13.1	9	137	95	6.1	2.89	7.03				
	7.5	11.27	800	24	3	1605	40.4	121.4	7.63	53.8	15.4	9	116	68	10.4	1.20	14.30	−1.12	−0.78	−182	−1.1
55E	0	10.76						101.9	6.23	45.2	12.3	9	156	110	3.9	5.92	4.30				
	7	9.38	700	19	2	1880	89.0	116.8	8.59	55.6	15.5	10	134	77	9.7	1.61	13.54	−1.38	−1.07	−212	−4.2
61D	0	13.61						105.2	6.21	48.2	13.2	8	142	152	7.0	3.81	5.23				
	8	12.08	900	18	2	2135	66.4	121.7	8.21	53.8	15.4	12	123	124	8.2	2.65	6.52	−1.53	−1.00	−177	+0.5
72D	0	10.02						105.9	5.52	56.4	14.7	6	140	89	3.8	5.09	4.78				
	7	9.04	630	16	2	1330	41.0	120.0	7.35	61.4	17.0	8	138	62	11.5	1.15	20.85	−0.98	−0.47	−129	+0.6

* ‖ See footnotes to Table I.

† Given as solution of 10 per cent urea in 5 per cent glucose.

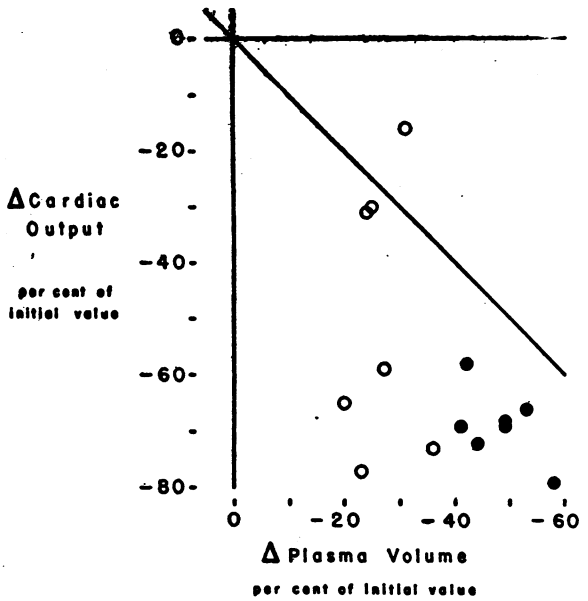

FIG. 4. COMPARISON OF PERCENTILE CHANGES IN CARDIAC OUTPUT WITH THOSE IN PLASMA VOLUME

Open circles represent water depletion, closed circles represent salt depletion.

In 4 of the water depletion and in all of the salt depletion experiments, the drop in cardiac output was proportionately greater than that in plasma volume.

cardiovascular responses in these 2 conditions differ only quantitatively. Mean arterial pressure and circulation rate do decrease somewhat with acute water depletion, although not as markedly as with salt depletion. Cardiac output in about half of the experiments with water depletion falls as far as it does with salt depletion.

There are indications that variables other than those specifically measured in these experiments are affected differently by salt and by water depletion. For example, the behavior of the animals with water depletion is vigorous and healthy, in sharp contrast to the lethargic state of animals depleted of salt.

In neither group of experiments is there a close correlation between the degree of drop in the plasma volume and the extent of the decrease in the cardiac output (Figures 3 and 4), nor do they necessarily occur simultaneously. Hence, any mechanical theory which relates the decrease in venous return and cardiac output simply to a drop in the volume of the plasma is inadequate. Changes in peripheral resistance to flow of blood, alterations in muscular contraction and muscular tone, both skeletal and cardiac, and other modifying factors must be operative. This in in agreement with evidence recently produced by other workers (28).

Attention has been called to the loss of circulating protein with salt depletion. This loss of protein, so closely associated with the disproportionate decline in plasma volume, suggests a causal relationship. With water depletion, plasma volume and extracellular fluid usually decline in proportion, and there is little loss of circulating protein (Figure 1). With salt depletion, the difference between the decline of plasma volume and that of the extracellular fluid is maximal when the loss of circulating protein is greatest, and is least when the loss of protein is minimal. Similar results are obtained by recalculation of the data of other workers (9, 29, 30).

The fate of the protein is unknown, but it is in all probability segregated somewhere within the body. Repeated analyses have proven that it is not lost into the peritoneal fluid. Current dynamic concepts picture a continuous exchange between the protein of circulating plasma and that outside the vascular spaces (31). Salt depletion or restoration may well displace the normal dynamic equilibrium in one direction or in the other.

The greater circulatory collapse produced by salt depletion may well be related to the loss of protein from the circulation. This in turn may favor a disproportionate decline in plasma volume and in venous return. Such an explanation must remain hypothetical, since all that can be stated positively is that a correlation exists. It is quite as logical to suppose that the salt depletion injures directly some part of the cardiovascular system and induces shock. The loss of protein may be merely a manifestation and not a cause. As extracellular salt is withdrawn, water moves in response to osmotic forces out of the extracellular fluid into the cells. Extracellular dehydration, intracellular overhydration, and hypotonicity of both compartments result. These changes may directly injure the cells of the heart or blood vessels and so indirectly may cause loss of circulating protein.

The implications of these experiments with regard to traumatic shock are clear. Extracellular salt depletion, if severe enough, will cause shock

without any element of trauma. Lesser degrees of depletion will obviously favor the development of shock due to other causes. Whenever there is any salt loss to the external environment or temporary segregation of salt by pooling in the gut, peritoneum, or in the traumatized region, shock will be produced with greater ease than would otherwise be the case. In many forms of traumatic shock, such as that produced by temporary anoxemia of a limb, this factor of salt loss may well outweigh all others in importance. In other types such as that associated with hemorrhage, it may be less important. It can hardly be wholly responsible for all shock, since treatment with an excess of saline will not invariably preclude the development of shock or cure it once it has developed.

CONCLUSIONS

1. Salt depletion in untraumatized animals produces a form of peripheral vascular collapse closely resembling that seen in traumatic shock. Plasma volume, cardiac output, circulation rate, and blood pressure all decline sharply, and protein disappears from the plasma.

2. Water depletion alone with a comparable decline in extracellular volume does not produce peripheral vascular collapse, although cardiac output, plasma volume, mean arterial pressure, and the circulation rate may decline. Usually little or no protein disappears from the plasma.

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