MINIMUM POSTOPERATIVE MAINTENANCE REQUIREMENTS FOR PARENTERAL WATER, SODIUM, POTASSIUM, CHLORIDE AND GLUCOSE*

ROBERT ELMAN, M.D., RICHARD A. LEMMER, M.D.,
THEODORE E. WEICHSELBAUM, PH.D., JAMES G. OWEN, M.D.,
AND RICHARD W. YORE, M.D.

ST. LOUIS, MISSOURI

FROM THE WASHINGTON UNIVERSITY SCHOOL OF MEDICINE,
DEPARTMENT OF SURGERY, AND BARNES HOSPITAL

UNDER NORMAL CONDITIONS of oral intake it is sometimes but not always easy to assure an adequate nutritional intake for the surgical patient. When the patient is unable to take anything by mouth and all intake must be parenteral, the responsibility of the surgeon increases; for while a definite measurable intake is more readily achieved, it is more difficult to know just how much of each element should be injected. Indeed, it is important to know just how little may be injected, i.e., the minimum needs to maintain normal function. Such knowledge is of practical value because it will avoid the inconvenience and expense of unnecessary, and the danger of excessive, injections. In order to study the probable minimum requirements, a series of observations were made on surgical patients given daily 2000 cc. of fluid containing glucose with and without added sodium chloride for four postoperative days. The findings suggest that a smaller intake of both water and salt than is usually given seems to be adequate. Moreover, specific data on potassium losses and glucose utilization were also obtained.

PREVIOUS WORK

The basis upon which surgeons estimate the water, electrolyte and glucose needs for the parenteral maintenance of the postoperative patient is, to a considerable extent, theoretical and traditional. In the early days of parenteral therapy large volumes were given, as much as four and five liters per day, not for the correction of deficits, but for maintenance of normal water balance. This was perhaps part of the then general belief in the value of a large fluid intake as illustrated by the still frequent order "force fluids." More significant than the large volumes injected was the fact that these fluids contained 9 Gm. of salt per liter because this was the only way in which isotonicity was achieved. Even when glucose was added later, the influence of tradition on the need for saline was not changed. Thus the amount of salt injected was often as great as 27 or even 36 Gm. per day, which is three to four times the intake of a normal individual. As might be expected, difficulties due to retention of fluid were produced though for a long time the casual connection was unrecognized. These difficulties were serious,

* Aided by a grant from the Commonwealth Fund. Read before the American Surgical Association, St. Louis, Mo., April 22, 1949.

and sometimes led directly to a fatal outcome. They arose because the human kidney could not excrete the large amount of salt, and therefore retained water with it to maintain the osmotic pressure of the body fluids. The clinical effects of this tremendous increase in body fluids were manifold —pulmonary edema, wound disruptions, peritonitis from failure of apposed peritoneal surfaces to heal, and circulatory impairment. So common did this danger become that Coller and associates[2] sounded an emphatic warning in 1944 in a report entitled *Postoperative Salt Intolerance.*

At the present time, most surgeons give the average adult postoperative patient unable to take anything by mouth 3000 cc. of water parenterally for maintenance alone, more to correct abnormal losses. Of this, one liter generally contains isotonic salt, so that the sodium chloride intake is nine Gm. a day, the amount an average normal individual is supposed to ingest in an average normal diet. Actually this may be much smaller, as indicated by analyses we have made on a number of patients on the usual hospital diets. As to glucose, the practice varies, some using 5 per cent glucose with or without amino acids, others a combination of 5 and 10 per cent glucose with or without amino acids. The intake of glucose and amino acids with three liters thus varies from 100 to a maximum of 300 Gm. of each.

Specific data on the minimum water, salt and glucose needs are rather limited. Cooper, Iob and Coller[3] have carried out carefully controlled studies of the urinary response for a period of only 30 hours after infusions of 5 per cent glucose in normal men and in patients following operations of varying magnitude. They observed a definite postoperative oliguria which was associated with a minimal output of sodium and chloride. Patients undergoing less severe operations, such as herniorrhaphy, as well as abdominoperineal resection, both experienced periods of low water output which later changed to diuresis. Sodium and chloride were excreted more rapidly during the periods of low water output, but were conserved during the diuresis stage. The average sodium loss was less (47.3 meq.) after abdominoperineal resection than after herniorrhaphy (107 meq.). Berry, Iob and Campbell,[1] in the same patients measured the potassium output in the first 30 hour postoperative period and found losses from 30 to 119 meq. The younger patients excreted more potassium than older ones undergoing the same operation, and those who had the more severe operative procedure, e.g., abdominoperineal resection, excreted on an average 73 per cent more free potassium than the controls who did not undergo any operation, or those subjected to herniorrhaphy. Howard[13] studied chronically ill surgical patients given an intravenous intake for six preoperative and six postoperative days. He found that on a constant intake of sodium and chloride (about 12 Gm. daily), despite considerable individual variations, most patients showed retention of salt after operation. He also found that on an intake of 50 meq. a day, more potassium was lost immediately after than before operation. The greatest loss occurred during the second postoperative day. This agrees with the findings of Reifenstein[16] who studied a patient after spinal fusion. Reifenstein also found that urinary excretion of sugar or reducing substances was increased after operation. The type of anesthesia and duration of operation are not mentioned.

PROCEDURE AND METHODS

In order to study this problem of minimum water, salt and glucose needs, balances were measured in a series of patients. We adopted first of all a volume intake of 2 liters, basing this on theoretical considerations. In various groups glucose was given in two concentrations, 5 and 10 per cent; in the latter concentration one series contained no salt intake, in another the intake consisted of 9 Gm. a day.

In all, 40 surgical patients were studied. They were unselected except for the criteria that they must have no clinical evidence of cardiovascular or kidney disease. The operations performed varied, although most of them consisted of uncomplicated cholecystectomy. Their preparation for operation did not necessitate special regimens such as blood, chemotherapy, etc. The preoperative medication was morphine and atrophine. All anesthesia was induced with sodium pentothal followed by gas-oxygen-ether. Nearly all cases were studied for an arbitrary experimental period of four consecutive days or 96 postoperative hours. A few patients were also studied before operation. During this time all intake was by intravenous injection. Any patient with a source for abnormal postoperative fluid or electrolyte loss (i.e., vomiting, biliary or gastro-intestinal drainage exceeding 100 to 200 ml.) was eliminated. Urine was collected during 24 hour periods and measured; an aliquot was obtained and preserved with toluol and refrigeration. The electrolyte content of small amounts of emesis occurring during the first postoperative day was included in the first 24 hour specimen. Heparinized samples of blood were withdrawn before operation and at the end of the study. Specific gravity and pH of the urine were determined by hydrometer and by glass electrode respectively. The urines were analyzed for sodium and potassium by means of the Weichselbaum-Varney flame photometer;[20] for chlorides by the method of Harvey,[11] for total nitrogen by the macro-Kjeldahl method of Hiller, Plazin and Van Slyke,[12] for creatinine by the method of Folin[7] adapted for the spectrophotometer, for acetone by the Legal nitroprusside test, and for sugar by the method of Somogyi,[17] for inorganic phosphates by the method of Fiske and Subbarow.[6] The plasma was analyzed for sodium and potassium by means of the Weichselbaum-Varney flame photometer,[20] for chlorides by the method of Van Slyke and Hiller,[19] for N.P.N. by the method of Folin[7] adapted for the spectrophotometer, and for plasma proteins by the method of Weichselbaum.[21] Hematocrit measurements were done on heparinized blood in a Wintrobe tube.

Blood transfusions were given several patients following operations other than cholecystectomy. The amount of blood was estimated to replace that lost during operation. In calculating balances no allowance was made for the electrolyte content of this blood except for the sodium citrate it contained. None of the patients undergoing cholecystectomy required blood replacement and it is this group of patients which were studied in greatest detail. These were divided into three groups.

One group of patients undergoing uncomplicated cholecystectomy received daily infusions of 2 liters of 10 per cent glucose in water; a second group

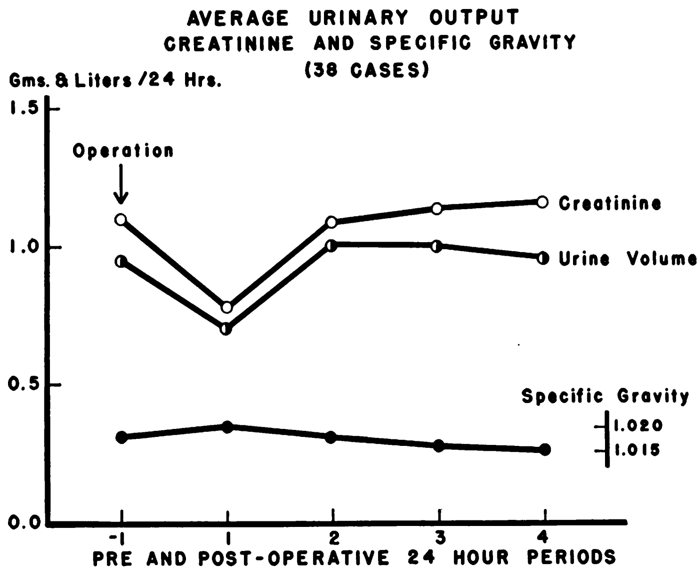

FIG. 1.—The graph represents the averages in 38 patients receiving an intake limited to 2 liters of intravenous glucose per day. Statistical analysis reveals that the changes from day to day were significant. Note the constancy of the specific gravity and the parallel fall in the creatinine content and urine volume in the first postoperative 24 hour period. Note also that after the first day the urinary output averaged one liter per day, which would be considered adequate.

received 2 liters of 10 per cent glucose in water to each of which 4½ Gm. of sodium chloride had been added; and a third group received 2 liters of 5 per cent glucose in water. Each patient's first infusion was started between 8 and 9 A.M., and his second between 4 and 5 P.M. The duration of each infusion was approximately three hours. There was no oral intake during the period of study. All patients were observed during the fall, winter and spring months.

FINDINGS

The findings are described under three headings: water, electrolyte and glucose.

Water.—The findings dealing with water balance are limited to measurements of urinary volume, creatinine, and specific gravity. Figure 1 shows the average daily pre- and postoperative values of 38 patients whose daily infusions consisted of 2 liters of 10 per cent glucose in water or 2 liters of 10 per cent glucose in water containing a total of 9 Gm. of NaCl. The addition of salt did not influence these findings. One notes that the daily urinary output approaches a liter per day except during the first 24 hour postoperative period. During this day the urinary output averages 750 ml. in comparison to 930 ml. for the day prior to operation, and 1000 ml. for the second and third postoperative days. These figures were subjected to careful statistical analysis and found to be significant in their day to day difference.

The oliguria noted during the first 24 hours after operation is accompanied by a fall in creatinine output, but without any change in specific gravity. Not every patient experienced this oliguria and the degree varied. The ages, which ranged from 19 to 75, did not seem to be a factor. The severity of the operation may be a factor but the number of various procedures studied was insufficient to draw definite inferences. Blood replacement at the time of operation in 12 cases did not seem to prevent oliguria during the first 24 postoperative hours. The operative records of these patients were examined and none had significant hypotension during their operations. In spite of the relatively normal urinary output, many of these patients experienced variable degrees of thirst which might indicate that the water intake was too low despite the adequate urinary output. However, there was no certain indication that this thirst was any different than it is in patients who received 3 liters of water. Controlled observations of this subjective symptom are difficult but perhaps deserve more study.

Electrolyte.—First of all are the observations on patients receiving no salt at all. These include 21 patients whose data are summarized in Table I. The operations were of various kinds, but the intake in all patients was limited to two liters of 10 per cent glucose intravenously a day. Scrutiny of these data reveals the fact that on no electrolyte intake and despite much individual variation, there is a conservation of salt as shown by a gradual decrease in the amount of sodium and chloride excreted on each consecutive day during the four day postoperative study period. Patients who received blood replacement on the day of operation tended to lose on an average slightly more sodium and chloride than those not needing blood replacement. In general, those receiving blood were the ones subjected to a more severe operation.

Age proved to be a factor in the individual variations in electrolyte conservation as shown by the data in the six cholecystectomized patients listed in Table I; three were young, aged 19, 27 and 28, and they excreted daily, over the 96 hour study period, an average of 7 meq. of Na and 17 meq. of chloride, in contrast to the older patients, aged 56, 59, and 64, who excreted twice as much, i.e., 20 and 34 meq. respectively. Thus, with no electrolyte

TABLE I.—*Postoperative Output in Urine Per 24 Hours*
Daily Intake 2000 cc. 10 Per Cent Glucose in Water

Case	Age Sex	Op.	Postoperative 24 Hour Periods																				Cumulative Loss			
			1					2					3					4								
			Na	K	Cl	P	N	Na	K	Cl	P	N	Na	K	Cl	P	N	Na	K	Cl	P	N	Na	K	Cl	N
1	19F	GB	28	45	37	24	3	19	14	30	13	6	13	13	13	7	4	2	7	13	11	6	62	79	93	18
2	56F	GB	.....	.....	.....	.....	.....	36	57	44	37	7	12	35	24	18	6	5	12	21	4	8	53	104	81	20
3	54F	GB	53	23	59	9	2	40	24	45	20	4	21	14	33	2	4	13	5	20	0	2	126	66	156	13
4	28F	GB	13	27	13	26	6	3	11	14	12	5	2	8	7	12	5	2	6	3	8	4	20	53	37	20
5	59F	GB	51	25	79	16	2	18	33	23	34	3	14	20	15	5	5	3	13	4	10	3	86	93	123	12
6	27F	GB	19	15	31	14	2	11	30	27	33	5	3	4	14	16	4	1	17	5	24	7	33	66	77	18
7	75F	GR*	32	18	29	15	4	30	23	24	17	8	52	44	40	35	11	.....	.....	.....	.....	.....	114	84	93	19
8	53F	GR*	40	21	40	26	5	81	28	17	28	8	33	50	65	38	22	31	29	40	8	14	184	128	162	49
9	72M	GR*	23	39	23	20	4	52	54	48	26	6	61	41	66	22	7	23	31	120	20	6	164	165	257	23
10	74M	JE	30	23	32	35	6	17	17	25	58	5	23	15	33	9	5	.....	.....	.....	.....	.....	70	54	89	16
11	58F	JE	5	2	12	1	3	6	2	12	1	2	7	2	10	5	2	2	8	33	12	6	20	14	63	13
12	59F	HY*	96	69	70	30	7	83	38	20	28	8	24	21	14	18	6	107	17	14	10	4	157	145	119	25
13	42F	HY*	19	36	42	3	4	15	37	34	5	7	7	19	19	10	6	5	14	17	15	8	44	106	111	25
14	41F	HY*	62	72	68	67	5	53	31	36	32	6	41	28	58	23	6	13	17	33	8	4	167	147	195	21
15	39F	HY	63	42	73	48	4	38	31	57	27	3	45	54	48	13	2	.....	.....	.....	.....	.....	146	127	179	8
16	39F	HY	42	38	27	8	3	8	38	23	6	8	8	10	22	33	11	8	20	15	43	10	66	105	87	32
17	37F	HY*	43	83	56	77	7	14	50	45	56	9	21	55	30	43	21	3	13	22	18	6	81	201	153	43
18	43F	RM*	60	75	62	67	7	37	66	83	49	8	16	30	41	18	8	22	38	59	36	11	144	209	245	34
19	40M	IH	18	13	26	12	3	30	42	53	37	10	9	51	47	38	10	7	24	29	38	10	64	129	157	32
20	31F	TH	101	112	91	99	11	10	17	23	49	4	11	16	14	35	4	11	14	18	24	4	134	157	146	23
21	32M	EL*	21	7	13	31	4	20	29	11	65	10	6	12	19	10	9	16	39	13	24	7	62	88	65	30

*Key: Same as in Table III.

intake, the younger patients seem able to conserve more Na and Cl than the older patients, when each is subjected to the same operation under similar conditions.

The pattern of electrolyte loss on no salt intake is shown graphically in Figure 2, which is based on the six cholecystectomized patients already mentioned. Although there were considerable individual variations, the average figures picture accurately the trend in all, i.e., the gradual fall in the amount of Na and Cl excreted, thus showing an efficient conserving

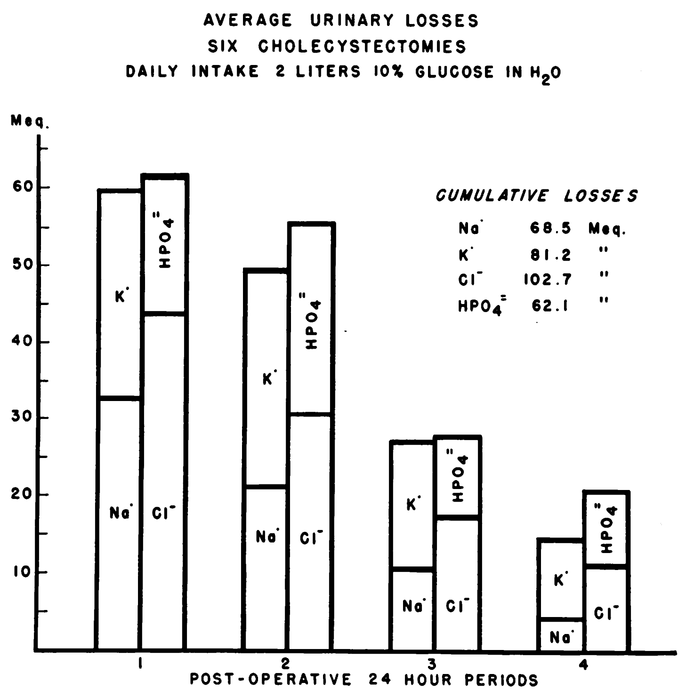

FIG. 2.—There was no salt intake in these patients. Note the decreasing output of sodium and chloride ion due to a conserving mechanism. Note, however, that the total average sodium loss during the 96 postoperative hours as sodium chloride was about 4 Gm. Note that the loss of potassium is more uniform and amounts, by the end of the 96 hour period, in terms of potassium chloride, to 6 Gm.

mechanism for these ions in the absence of any intake. On the other hand, potassium and phosphate tended to be excreted at a uniform rate during the first two 24 hour periods, and in some cases had a greater output during the second 24 hour period than during the first. The 96 hour cumulative loss was fairly small (Na 68 meq., K 81 meq., Cl 103 meq., HPO_4 62.1 meq., N. 16.9 Gm.) and represents about 4 Gm. calculated as NaCl and 6 Gm. calculated as KCl. It is not surprising, therefore, that this loss was accompanied by no significant changes in the blood levels of these electrolytes nor by any alteration in the CO_2 combining power, serum protein or hematocrit. (Table IV)

In order to compare the salt loss before with that after operation, one patient (Fig. 3) was given glucose in water during two preoperative periods. The same decrease in output of Na and Cl was again seen. The operation *per se* did not seem to affect this pattern of salt conservation in that the progressive fall in excretion of Na and Cl continued. On the other hand, potassium and phosphate behaved differently, i.e., more was excreted postoperatively, especially in the second postoperative 24 hour period.

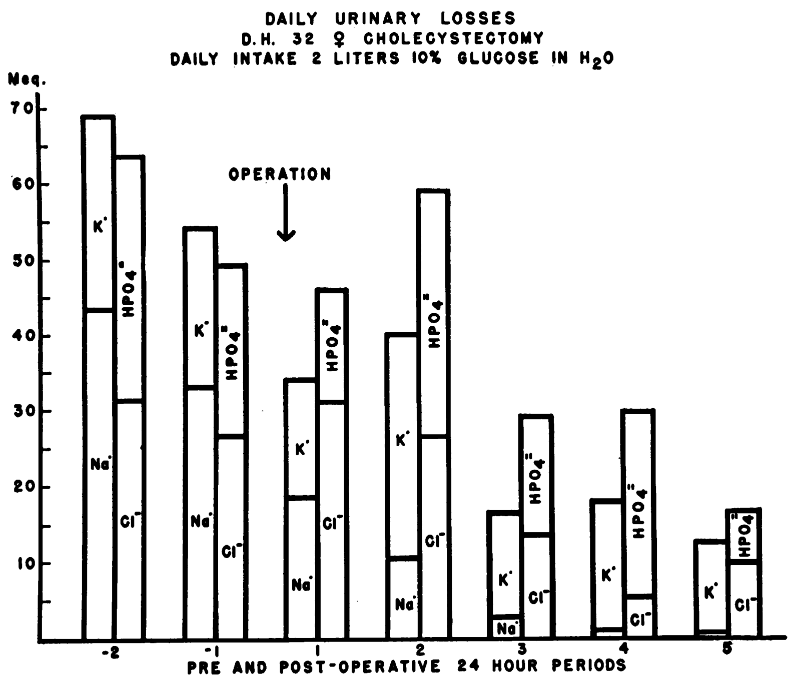

FIG. 3.—Pre- and postoperative urinary losses in electrolyte. This patient was given no salt before or after operation. Note that the pattern of conservation of sodium and chloride ion is not influenced by the operation. On the other hand, note the consistent and even increased loss of potassium and phosphate as influenced by operation.

In the next group of patients, the same regimen was carried out except for the addition of 9 Gm. of sodium chloride a day. Table II summarizes the urinary losses of 11 patients receiving daily intravenous infusions of 2 liters of 10 per cent glucose, each liter containing 4.5 Gm. of sodium chloride. The individual variations are great, but the findings show a pattern of retention of sodium and chloride similar in each patient. This is shown especially by the graphic representation (Fig. 4) in the five patients who underwent an uncomplicated cholecystectomy. For the first 24 hour postoperative period 76 per cent of the sodium injected and 70 per cent of the

TABLE II.—*Postoperative Output in Urine Per 24 Hours*
Daily Intake 2000 cc. 10 Per Cent Glucose in One Half Isotonic Saline

Case	Age Sex	Op.	Postoperative 24 Hour Periods 1					2					3					4					Cumulative Balance			
			Na	K	Cl	P	N	Na	K	Cl	P	N	Na	K	Cl	P	N	Na	K	Cl	P	N	Na	K	Cl	N
1	51F	GB	33	25	39	18	2	146	94	150	100	9	134	10	132	18	7	90	6	89	27	4	+209	−134	+205	−22
2	59F	GB	21	8	20	32	4	39	14	33	21	7	190	13	157	12	7	131	8	90	9	9	+234	− 42	+318	−26
3	53F	GB	31	17	41	17	2	26	11	61	26	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...
4	46F	GB	23	12	27	8	1	139	60	154	42	7	125	26	145	11	5	63	22	103	36	4	+266	−120	+185	−17
5	48F	CO*	50	27	53	39	3	94	42	185	13	9	151	32	154	6	7	131	27	167	6	5	+190	−128	+138	−24
6	58F	AP*	54	44	72	17	5	75	26	90	4	7	116	16	151	16	6	108	10	127	4	4	+362	− 97	+313	−23
7	71F	SR*	25	28	48	24	4	132	30	129	32	7	165	23	169	8	6	91	19	109	6	5	+139	−100	+ 84	−21
8	53F	TC	97	31	99	15	9	129	31	146	16	11	185	7	191	13	6	199	15	212	13	5	+ 6	− 83	− 34	−32
9	46F	EL*	102	52	160	38	6	56	25	68	27	4	139	21	153	14	4	170	18	169	....	4	+162	−116	+ 64	−18
10	71F	GR*	27	24	25	28	2	101	75	77	32	11	137	54	93	23	8	108	15	70	6	7	+207	−168	+351	−28
11	44F	GB	75	75	103	38	5	126	49	145	37	6	149	30	140	6	5	73	11	80	4	3	+192	−165	+149	−19

*Key: Same as in Table III.

chloride was retained. Of the total 9 Gm. of sodium infused during the first 24 hour period, this represents a retention of nearly 7 Gm. of NaCl. Retention of both Na and Cl continue during the second 24 hour period and during the third 24 hour period the excretion of sodium and chloride approaches the intake. The cumulative retention of Na and Cl for the 96 hour study period averages 39 per cent for Na and 37 per cent for Cl. This is equivalent to a retention of about 14 Gm. of the 36 Gm. of sodium chloride infused over the 96 hour period. The cumulative loss of K averaged 110.7 meq. and of HPO_4 98.5 meq.

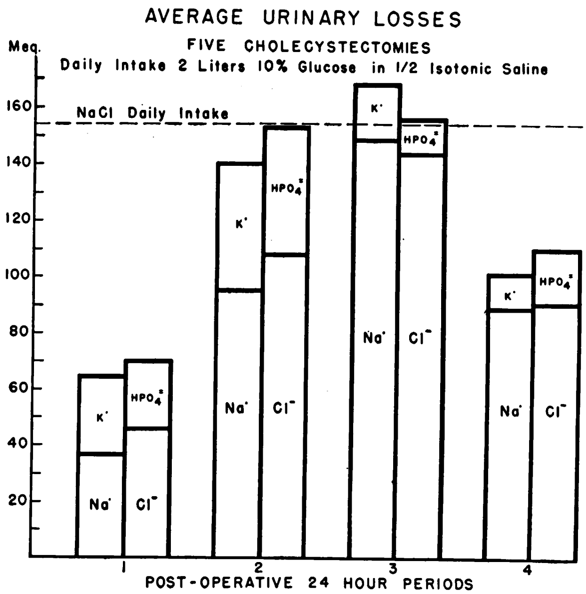

FIG. 4.—These patients received 9 Gm. of salt each day, equally divided between the 2 liters of 10 per cent glucose. Note the retention of sodium and chloride ion most marked on the first day and then decreasing. Calculation of the averages in this group showed that about 40 per cent of the injected sodium chloride was retained by the body. Note on the other hand the consistent losses of potassium and phosphate, which indeed were greater on the second than the first day.

In order to show the influence of preoperative intake, the data on one patient, a 42-year-old female who underwent an uncomplicated cholecystectomy is shown in Figure 5. She was given 2 liters of 10 per cent glucose and 9 Gm. of sodium chloride both before and after operation. This patient was ill prior to her admission to the hospital and had not been eating normally, but had not vomited. Note the retention of both Na and Cl preoperatively. This is similar, though even more marked in degree than the postoperative retention of sodium chloride of the patients in Figure 4. After operation, however, there was a retention of only 24 per cent of the Na and

TABLE III.—*Postoperative Output in Urine Per 24 Hours*
Daily Intake 2000 cc. 5 Per Cent Glucose in Water

Case	Age Sex	Op.	Postoperative 24 Hour Periods																				Cumulative Loss			
			1					2					3					4								
			Na	K	Cl	P	N	Na	K	Cl	P	N	Na	K	Cl	P	N	Na	K	Cl	P	N	Na	K	Cl	N
1	36F	GB	10	8	13	6	1	37	43	77	31	5	3	21	32	14	4	6	10	14	16	3	55	82	135	13
2	64F	GB	28	25	74	22	2	49	96	55	9	11	8	23	23	4	7	1	5	20	11	7	86	149	170	27
3	46F	GB	21	45	46	40	5	26	37	65	30	8	12	19	27	12	5	5	13	15	15	6	63	112	152	25
4	23F	GB	3	28	13	34	7	1	14	0	44	5	.5	9	7	...	...	...	...	...	...	...	...	...	...	...
5	61F	EL	19	59	16	70	8	18	27	8	45	11	35	25	28	34	8	9	17	8	23	7	45	135	59	34
6	67F	AP*	9	5	15	34	5	7	25	21	26	8	6	15	32	23	7	...	...	...	...	...	22	44	114	21
7	35M	EL	40	114	70	90	11	3	13	14	17	5	7	12	11	21	6	6	34	17	5	14	56	172	116	35
8	36F	GB	88	65	134	5	6	69	37	57	1	8	13	17	18	1	5	10	16	18	3	6	179	135	181	25

Key:

All values expressed as milliequivalents except nitrogen (N) which is expressed as grams.

*—Patients given blood at operation.
GB—Cholecystectomy.
GR—Gastric Resection.
JE—Jejunostomy.
HY—Hysterectomy.
RM—Radical Mastectomy.
IH—Incisional Herniotomy.
TH—Thyroidectomy.
EL—Exploratory Laparotomy.
CO—Colectomy.
AP—Abdominal Perineal Resection
SR—Sigmoid Resection.
TC—Transverse Colostomy.

4 per cent of the Cl infused during the first 24 hour period, which is much lower than average. The output of NaCl approached the intake during the third day. The cumulative retention at the end of seven days of study, during which the same intake was given each day entirely by vein, was 125 meq. of Na and 159 meq. of Cl. This is equivalent to a retention of roughly 12 per cent of the sodium and 15 per cent of the chloride, or in grams, a retention of only 7 to 9 Gm. of the 63 Gm. of NaCl infused during this period, much less than the average as previously noted.

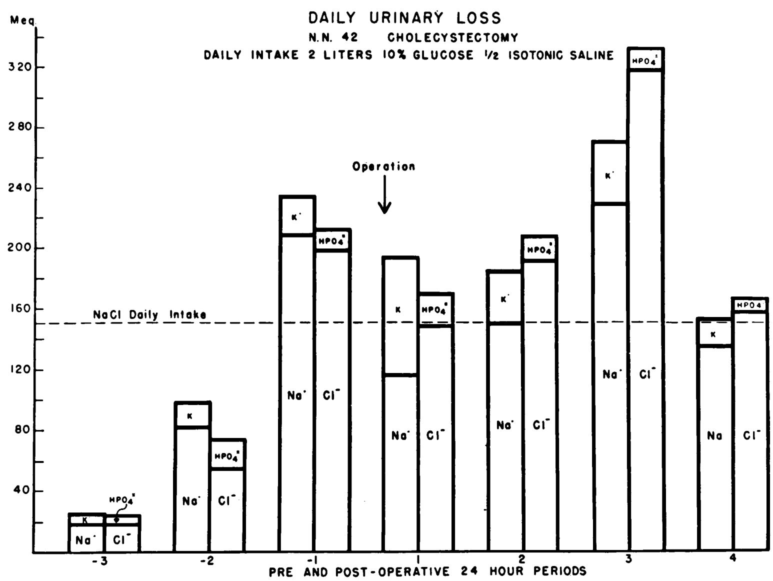

FIG. 5.—This patient received the same amount (9 Gm.) of NaCl both before and after operation. Note that there was an even greater degree of retention of sodium chloride before operation as compared with the findings in Figure 4, presumably due to the fact that the patient took very little but water before this preoperative period of observation. Note also that the degree of retention after operation was less pronounced than in the cases shown in Figure 4, thus illustrating the influence of previous salt intake.

The effect of a reduction in intake of glucose on electrolyte behavior is shown in Table III. This summarizes the electrolyte and nitrogen losses of eight patients receiving by daily intravenous injection 100 Gm. of glucose, i.e., 2 liters of 5 per cent glucose in water. The 96 hour cumulative losses are fairly small (Na 88 meq., K 108 meq., Cl 144 meq., HPO_4 63 meq., and N 22.4 Gm.), but somewhat greater on an average than those patients receiving 200 Gm. of glucose. Moreover, these losses were similarly accompanied by no significant changes in the blood levels of these electrolytes nor by any significant alteration in the CO_2 combining power, serum proteins or hematocrit. (Table IV)

Glucose.—The findings in regard to glucose concern the observed differences between an intake of 100 Gm. and one of 200 Gm. First of all are the

TABLE IV.—*Pre- and Postoperative Blood Chemical Measurements*

Pt	Operation	Intake/Liters	Pre-operative Blood Cl	Pre-operative Blood CO_2	Pre-operative Blood Na	Pre-operative Blood K	Pre-operative Blood A	Pre-operative Blood G	Pre-operative Blood T	Pre-operative Blood NPN	Pre-operative Blood Hcrit	Post-operative Blood Cl	Post-operative Blood CO_2	Post-operative Blood Na	Post-operative Blood K	Post-operative Blood A	Post-operative Blood G	Post-operative Blood T	Post-operative Blood NPN	Post-operative Blood Hcrit
MC	Cholecystectomy	2.0 10% ½ISS	108.0	63.5	145.0	4.61	5.22	2.68	7.90	15	43.8	99.5	65.5	142.5	4.30	5.50	3.05	8.20	17	42.4
DR	Cholecystectomy	2.0 10% ½ISS	92.0	....	137.0	2.55	4.50	3.00	7.50	..	42.8	100.5	75.5	146.7	3.00	3.86	3.29	7.15	28	38.8
FL	Cholecystectomy	2.0 10% ½ISS	114.6	57.8	140.0	4.30	4.95	2.85	7.80	17	42.6	118.0	65.8	137.5	3.38	4.17	2.78	6.95	16	36.9
EP	Cholecystectomy	2.0 10% ½ISS	116.0	64.0	148.5	3.78	4.78	2.42	7.20	19	48.0	.....	63.1	150.0	3.65	3.70	2.60	6.30	17	42.0
LR	Ileo-Sigmoidostomy	2.0 10% ½ISS	102.5	61.1	140.5	3.72	5.49	3.21	8.70	12	44.4	120.0	70.6	.....	....	3.90	2.65	6.55	21	30.2
AF	Abd. Peri. Res.	2.0 10% ½ISS	107.5	63.3	142.0	4.00	5.85	3.95	9.80	21	44.3	103.0	62.9	141.3	3.70	5.23	3.37	8.60	16	39.5
LA	Res. Primary Anast.	2.0 10% ½ISS	111.0	70.0	135.0	4.80	4.49	3.66	8.15	21	44.0	106.0	....	140.6	4.56	3.57	3.82	7.40	..	38.0
EG	Trans. Colostomy	2.0 10% ½ISS	116.0	69.9	145.0	3.67	4.56	2.19	6.75	29	44.0	110.0	74.0	139.0	3.26	3.90	2.75	6.65	21	44.0
FH	Gastrotomy, Exp. Lap.	2.0 10% ½ISS	118.0	60.7	146.0	4.40	4.35	2.45	6.80	25	44.0	114.0	74.7	147.1	3.66	3.86	2.04	5.90	13	39.0
CM	Subtotal Gastrectomy	2.0 10% ½ISS	110.0	71.3	140.5	4.95	3.19	2.19	5.38	31	41.0	117.0	....	.....	....	3.46	2.54	6.00	....	36.0
NN	Cholecystectomy	2.0 10% ½ISS	123.0	57.8	151.0	3.36	4.64	2.76	7.40	13	38.0	116.0	72.6	146.0	3.59	4.21	2.64	6.85	12	39.0
MS	Colectomy, Trans.	2.0 10% ½ISS	120.0	65.0	144.0	3.59	4.56	3.14	7.60	14	43.0	117.0	72.4	154.9	3.36	3.84	2.71	6.55	23	41.7
PB	Cholecystectomy	2.0 10% ½ISS	88.0	61.5	138.9	4.04	5.17	2.08	7.25	17	36.0	121.0	71.7	148.0	3.96	4.17	2.68	2.85	14	39.0
MG	Cholecystectomy	2.0 10% HOH	111.0	59.0	145.0	6.00	5.10	1.90	7.00	15	41.0	106.0	55.6	141.0	5.05	4.60	2.30	6.9	20	37.6
MG	Cholecystectomy	2.0 10% HOH	.....	....	.....	....	....	....	....	..	....	105.0	68.1	142.0	4.60	4.40	3.10	7.5	25	39.8
FH	Cholecystectomy	2.0 10% HOH	.....	....	.....	....	....	....	....	..	....	105.0	60.8	147.5	4.20	4.40	2.90	7.3	..	....
EH	Cholecystectomy	2.0 10% HOH	102.5	....	142.0	5.50	4.60	3.20	7.80	..	44.0	99.0	57.6	134.0	4.20	4.30	3.50	7.8	42	44.0
DH	Cholecystectomy	2.0 10% HOH	.....	....	.....	....	....	....	....	..	....	97.0	62.1	135.0	4.10	4.30	3.00	7.3	12	41.0
MT	Gastric Resection	2.0 10% HOH	104.3	51.9	140.5	4.73	4.47	3.53	8.00	31	48.6	88.0	56.7	131.0	4.55	4.41	3.69	8.1	31	47.7
CV	Gastric Resection	2.0 10% HOH	108.0	16.1	145.0	5.90	5.90	3.50	9.40	25	44.5	98.0	69.5	135.1	6.01	4.48	3.62	8.1	25	25.7
WP	Gastric Resection	2.0 10% HOH	110.7	60.6	137.3	5.62	4.86	2.09	6.95	32	37.0	98.0	....	136.2	5.00	4.16	2.99	7.15	..	40.0
MC	Abd. Pan Hysterectomy	2.0 10% HOH	103.0	69.8	134.0	4.23	4.95	4.25	9.20	18	40.9	95.0	76.7	.....	....	4.67	4.53	9.2	20	....
FW	Abd. Hysterectomy	2.0 10% HOH	104.0	61.6	136.8	4.24	5.24	3.26	8.50	15	34.0	98.5	66.6	137.5	3.70	5.60	3.10	8.7	18	33.0
DO	Hysterectomy	2.0 10% HOH	106.5	66.9	132.4	4.25	3.68	7.67	6.35	19	40.0	96.5	65.0	.....	...	5.10	3.25	8.35	20	43.3
NH	Abd. Pan Hysterectomy	2.0 10% HOH	101.5	66.0	140.2	4.24	5.16	3.84	9.00	21	34.4	98.5	60.6	133.0	4.00	4.95	2.75	9.7	24	31.2
MP	Abd. Hysterectomy	2.0 10% HOH	102.5	28.8	138.0	4.53	5.23	3.47	8.70	17	37.6	97.5	59.5	132.2	3.85	5.72	3.38	9.1	20	31.6
RD	Hysterectomy	2.0 10% HOH	107.5	58.5	136.5	5.30	4.94	3.66	8.60	17	34.9	101.5	65.4	142.0	4.13	4.48	3.52	8.0	..	....
KR	Inc. Hernia Repair	2.0 10% HOH	110.0	60.5	145.0	6.72	5.85	2.75	8.60	18	48.0	106.0	61.9	136.2	5.90	5.34	2.76	8.1	22	48.9
HH	Thyroidectomy	2.0 10% HOH	105.2	55.7	143.7	5.60	4.68	2.42	7.10	14	48.0	106.0	55.0	144.0	5.68	4.90	3.60	8.5	17	46.0
BB	Exp. Laparotomy	2.0 10% HOH	100.5	64.4	145.0	6.93	4.10	1.90	6.00	24	30.0	101.0	55.0	138.5	5.10	4.80	2.40	7.2	24	38.8

All patients received 10% glucose in water (HOH) or in half strength isotonic saline (½ ISS).
Key: All measurements of Cl, CO_2, Na and K were made in plasma and expressed as meq/liter.
A, G, T refer to Albumin, Globulin and Total Proteins in Plasma, expressed in Gm. per cent.
NPN refers to nonprotein nitrogen of plasma as mg%.
Hcrit is the hematocrit value expressed as a percentage of the whole blood volume.

nitrogen losses. These were surprisingly low in both groups. (Tables I, II and III.) On an average, but 20 to 25 Gm. of nitrogen were lost during the entire four day postoperative period or about 4 to 5 Gm. a day. Only two specimens contain more than 20 Gm., one on the third day following a gastric resection, the other on the third day following hysterectomy. Only 17 specimens of the nearly 160 examined contained 10 Gm. or more of nitrogen. Moreover, comparison of the nitrogen loss in patients receiving 100 with those receiving 200 Gm. of glucose reveal little difference, i.e., 26 as compared with 23 Gm. for the average total 96 hours. Scrutiny of the individual cases also reveals no significant difference.

In all three groups, glycosuria and acetonuria were observed (See Table V). Of eight patients receiving daily intravenous infusions of 2 liters

TABLE V.—*Glycosuria and Acetonuria Following Operation*
Daily Intake 2000 cc. per 24 Hours

	I 5% Glucose (100 Gm.) in Water	II 10% Glucose (200 Gm.) in Water	III 10% Glucose (200 Gm.) in ½ Isotonic Saline
Number patients studied	8	10	11
Patients showing glucosuria	6	10	11
Average amount glucose spilled (Gms.)	12.9	18.4	34.1
Range in amount glucose spilled (Gms.)	2.2—24.3	1.5—88.0	6.1—82.8
Av. rate of infused glucose in Gms./kg. body wt./hr.	.23	.48	.52
Patients showing acetonuria	6	2	6
Number 24 hour urine collections examined	31	37	39
24 hour urine collections containing acetone (%)	52	5	21
24 hour urine collections containing glucose (%)	42	86	92
Av. cumulative 96 hour urinary Na loss (meq.)	72	87	(197)*
Av. cumulative 96 hour urinary K loss (meq.)	118	103	115
Av. cumulative 96 hour urinary Cl loss (meq.)	132	126	(177)*
Av. cumulative 96 hour urinary P loss (meq.)	1.82	1.27	1.28
Av. cumulative 96 hour urinary N loss (Gms.)	26	29	23

*This figure represents positive balance, i.e., retention of the injected sodium chloride in this group.

of 5 per cent glucose and water for four postoperative 24 hour periods, six had glycosuria at some time during this period and 42 per cent of the 24 hour urine specimens contained glucose. The average amount was 13 Gm. The range in degree of glycosuria varied from as little as 2.2 Gm. of sugar to 24.3 Gm. It should be emphasized, however, that the average rate of infusion was 0.23 Gm. per Kg. of body weight per hour. As to acetonuria, six of these eight patients showed a positive test at some time during their postoperative period and 52 per cent of the 24 hour urine specimens contained from traces to 4 plus acetone. Five of the six patients having acetonuria also showed glycosuria during the same 24 hour period on one or more occasions during the four days of study.

Of the patients receiving daily infusions of 2 liters of 10 per cent glucose and water, 10 with and 11 without added electrolyte, all had glycosuria and

86 and 92 per cent of the 24 hour urine specimens contained glucose respectively. The average amount spilled was 18 and 34 Gm. respectively, and the range varied from 1.5 to 88 Gm. of glucose. It should be emphasized that the average rate of infusion was 0.48 and 0.54 Gm. per Kg. of body weight per hour, or twice that of those receiving 5 per cent glucose. Only eight of the 21 patients had acetonuria varying from traces to 2 plus; all eight patients at one time or another had acetonuria and glycosuria during the same 24 hour period. Only minor differences were discernible between those receiving 10 per cent glucose in water and those receiving 10 per cent glucose in saline.

DISCUSSION

The objective regarding minimum needs suggested in the title of this report has only been partly met by the evidence herein presented. Nevertheless, a few inferences may be drawn as to how little the postoperative patient may be given to maintain normal function. It should be mentioned at the outset however that such inferences are based upon the assumption that balance studies are valid as a guide to estimating such needs. This assumption has the sanction of general acceptance. Moreover, it is logical to believe that in the absence of deficits, intake of each element should balance the output just as energy intake equalizes energy expenditure. One of the possible pitfalls is the statement "in the absence of deficits," the truth of which may be difficult to establish in each individual patient. Another pitfall is the possibility that even in the absence of deficits some elements may be retained with physiological improvement, or that, vice versa, a "negative balance" may be beneficial because the body wishes to rid itself of an excess of a normal biochemical constituent. In spite of these and perhaps other objections, inferences will be based upon the validity of the idea that a balance of intake and output indicates an optimum physiological state.

The data on water balance seem to indicate that in the normally hydrated adult 2 liters is an adequate fluid intake in the absence of pathological losses. This is shown by the fact that this intake was accompanied by an adequate urinary output. Body weights, it is true, were not determined, and this would have given accurate confirmation as to the amount of insensible water losses. However, the average difference between intake and urinary output was about one liter, which is roughly that of the insensible loss. Thus it is likely that the fall in body weight would have been approximately one Kg. per day plus whatever loss was due to an inadequate caloric or nitrogen intake. Thirst might be considered as a guide to the measure of water needs. As already mentioned, however, so many postoperative and post-traumatic patients experience thirst, even on a larger water intake, that its significance remains unestablished. The fact that blood studies showed no change in electrolyte concentration or hematocrit would seem to indicate that dehydration did not occur on this intake. Thus it would seem justified to infer that 2 liters are all that are necessary to maintain water balance in the postoperative patient. This agrees rather well with data obtained on normal humans subjected to starvation. [8, 10, 24]

The oliguria observed on the first postoperative day was not unexpected since it is a common clinical observation that patients seldom excrete as much urine during this period as they do later. Of greater interest was the fall in the creatinine output with no change in specific gravity. Since creatinine is cleared by the kidneys so readily, and concentrating function is performed by the tubules, it would seem that the oliguria was due to a decrease in the effective renal plasma flow and filtration fraction. Further observations, however, are necessary to be sure that this was the correct explanation.

The electrolyte needs may be partially estimated from the findings herein recorded. It is true that the loss during an intake of water and glucose alone was not very great, and was accompanied by no fall in the electrolyte composition of the blood. However, even small losses are probably not without some significance. It would be a simple matter indeed to provide this intake by the addition of a few grams of sodium and potassium salts. On the other hand, the addition of 9 Gm. of sodium chloride seems too great inasmuch as there was a retention averaging about 40 per cent of that injected. The degree of retention is certainly greatly influenced by the previous intake, i.e., the lower the intake before operation the greater the degree of retention. This is due to a fairly well known lag in the ability of the human kidney to excrete salt above the previous level of intake. This is true under normal conditions of oral intake as shown by White and Findley,[22] and is especially true after operation as shown by Stewart and Rourke[18] and others. Whether operative or accidental trauma and anesthesia increase this lag cannot be inferred from the present data. Further studies with careful comparison of pre- and postoperative retention is needed. In any case, it would seem, on the basis of the present observations with a daily intake of 9 Gm. of NaCl, that 4 Gm. would probably not lead to retention. On the basis of the much smaller sodium chloride losses on no intake, a balance may be struck, indicating that an average of between 2 and 4 Gm. of sodium chloride a day would probably produce balance in the average patient. The need for adding potassium rests on the assumption that losses in this element should be replaced. On such a basis about one to 2 Gm. of potassium salt should be added to the daily intake. If both salts were added as the chloride, a much larger amount of chloride would be present than seems to be needed on the basis of the present findings. Cations can readily be added without anions in the form of sodium or potassium lactate or gluconate. This does not take into account other electrolytes such as magnesium and perhaps the anions sulfate and phosphate. Further observations will be needed before their requirements can be definitely established.

It must be admitted, of course, that for short periods of time it is unlikely that serious physiological impairment will follow small deficits in these electrolytes, such as might follow their deprivation. Thus it might be argued that simple fluids without salt might be adopted as routine. The difficulty with this point of view is that one never knows when the parenteral route may be required for longer than a few days. Furthermore, exact replacement, while not always essential, is a better basis for therapy than conclusions drawn from the results of experience alone. Further observations are being made in order to determine more accurately what pattern of electrolyte intake will lead to balance under normal conditions.

Findings in regard to glucose needs may be discussed in two parts. First is its sparing effect on tissue protein breakdown. As will be noted, the tissue protein loss as measured by the nitrogen excretion in the urine was surprisingly low in all of the cases studied, indicating that in these instances at least there was very little catabolic reaction, a finding which is contrary to many we have previously made and which have been made by others.[4, 5] It is, therefore, not surprising that there was very little difference in the nitrogen loss when the glucose intake was 200 Gm. as compared with 100 Gm. This would seem to confirm the finding of Gamble[10] that in normal human beings an intake of 100 Gm. of glucose a day produces the maximum sparing effect on tissue protein breakdown, and that an increase to 200 Gm. does not decrease the tissue protein loss. It should be mentioned, however, that in the present observations a variable amount of glucose was lost in the urine, and that this loss was greater in those receiving 200 Gm. Thus the effective amount of glucose available for metabolic needs was much less than 200 Gm. and indeed in one case, was only about a little over 100 Gm. It seems unlikely, however, that even with full utilization of the entire 200 Gm. further reduction in the low nitrogen loss could be effected.

The second finding concerns the degree of glycosuria and acetonuria observed. Glycosuria and acetonuria were noted in a large percentage of the cases studied. Since the rate of injection even with the 10 per cent solution was fairly low, i.e., 0.52 Gm. per Kg. per hour, the appearance of glycosuria must be taken as an indication that the postoperative patient operated under gas-oxygen-ether anesthesia under the present circumstances cannot utilize glucose as well as the normal.[14] Even when the rate was half this, i.e., 0.25 Gm. per Kg. per hour, as was the case with the 5 per cent solution, sugar was still spilled in the urine. It is probable that this glycosuria might have been avoided if the injection had been started at a slower rate in accordance with the Staub effect, as reported by Pareira and Somogyi.[15]

Acetone in the urine occurred more frequently when 5 per cent glucose was given than when 10 per cent glucose was injected. Pareira and Somogyi[15] observed ketonuria in a postoperative patient during the injection of 5 per cent glucose, which disappeared with a change to 10 per cent glucose. We have no data as to the exact significance of this finding inasmuch as 24 hour urine specimens only were measured. The appearance of a small amount of acetone during even one or two hours of the total 24 hour period, while of little significance, would give a positive result. Nevertheless, it must be admitted that even a small amount of acetone in the urine under these conditions means that at some interval of time during the 24 hours the liver was probably free of glycogen, or that ketone bodies were being produced more rapidly than they could be utilized.

From the findings herein presented and from other considerations, it would seem safe to conclude that a full caloric quota by the injection of 4 liters of 10 per cent glucose is not ordinarily necessary nor indeed desirable. First it would probably not spare any more tissue protein, and in fact merely would spare the breakdown of tissue fat. Moreover, it is unlikely that, without special control of the rate of injection, all of this amount could be utilized by the body after operation, but that much of it would appear in the urine. Finally, the mechanical problem of administering this much glucose would seem too great to be justified. Nevertheless, the appearance of acetonuria on the lower intakes deserves careful scrutiny. The claim of Pareira and Somogyi[15] that up to 350 Gm. spaced over the entire 24 hour period is needed to avoid ketosis suggests the need for further study of this question.

Glucose utilization is, of course, influenced by many factors, and it is probable that the use of gas-oxygen-ether anesthesia plays an important role. For example, it is likely that the same operative procedures carried out under spinal anesthesia might provoke much less glycosuria and acetonuria. The mechanism of these disturbances in carbohydrate metabolism as herein observed deserves further investigation.

The significance of the potassium losses may be discussed in terms of protein losses. This is usually done by establishing a K/N ratio based upon computing the potassium loss in millimols and the nitrogen loss in grams. This has been calculated in 26 of the patients observed in this study. Only six of them showed a value below three, and in most of them the figure was between four and six. A ratio of three or less is considered by most authorities to represent the normal relationship of intracellular potassium to protein. Our findings, therefore, suggest that the destruction of the patient's protoplasm was not the sole source of the potassium loss, and that much of it originated in another way, perhaps by loss of cell potassium without loss of protoplasm.

SUMMARY

1. Balance studies were carried out in 40 surgical patients on a completely intravenous intake for 96 postoperative hours, and in a few cases during several preoperative days. Study of the urinary output included volume, specific gravity, creatinine, sodium, potassium, chloride, phosphate, nitrogen, glucose and acetone. Blood levels of sodium and potassium chloride, CO_2, plasma protein and red cell volume were also measured before and after each study.

2. With an intake limited to 2 liters a day there was an adequate urinary output during the four postoperative days of about one liter except for a moderate oliguria during the first postoperative day. The oliguria was accompanied by a decreased creatinine excretion with no change in specific gravity.

3. With no electrolyte intake, the body rapidly conserves sodium and chloride, but not potassium and phosphate. The cumulative loss during four postoperative days averaged about 4 Gm. calculated as sodium chloride and 6 Gm. calculated as potassium chloride. No changes in plasma levels of sodium, potassium, CO_2, proteins or in red cell volume were observed on this intake.

4. With an intake of 9 Gm. of sodium chloride a day, there was a definite lag in excretion so that of the 36 Gm. injected, an average of about 14 Gm. was retained. The loss of potassium, however, was the same.

5. It is estimated from these findings that an intake of 2 liters of water plus 2 to 4 Gm. of a mixture of sodium and potassium chloride (or gluconate) would meet the minimum requirements for these elements in the postoperative patient.

6. Calculation of the potassium-nitrogen excretion ratio suggests that only part of the potassium loss originated from the breakdown of tissue protoplasm.

7. The nitrogen sparing effect of 200 Gm. of glucose was not significantly greater than 100 Gm. of glucose. On the other hand, because of an undoubted disturbance in carbohydrate metabolism, acetonuria was more frequent under the latter than under the former intake. Glycosuria conversely was greater with a 200 Gm. intake as compared with a 100 Gm. intake. In order to determine the minimum requirements for glucose, further observations will be necessary, particularly with regard to the influence of the rate of injection.

BIBLIOGRAPHY

[1] Berry, R. E. L., V. Iob, and K. N. Campbell: Arch. Surg., **57:** 470, 1948.
[2] Coller, F. A., and Associates: Ann. Surg., **119:** 533, 1944.
[3] Cooper, D. R., V. Iob, and F. A. Coller: Ann. Surg., **129:** 1, 1949.
[4] Cuthbertson, D. P.: Lancet, **2:** 433, 1942.
[5] Elman, R.: Ann. Surg., **112:** 594, 1940.
[6] Fiske, C. H., and J. Subbarow: Biol. Chem., **66:** 375, 1925.
[7] Folin, O., and H. Wu: J. Biol. Chem., **38:** 81, 1919.
[8] Futcher, P. H., W. V. Consollazio and N. Pace: War Med., **5:** 203, 1944.
[9] Gamble, J. L.: Chemical Anatomy, Physiology and Pathology of Extracellular Fluid. Cambridge, Massachusetts. Harvard University Press, 1942.
[10] Gamble, J. L.: Harvey Lectures, 1946–47. p. 247.
[11] Harvey, S. C.: Arch. Int. Med., **6:** 12, 1910.
[12] Hiller, A., J. Plazin and D. D. Van Slyke: J. Biol. Chem., **176:** 1401, 1949.
[13] Howard, J. E.: Conference on Metabolic Aspects of Convalescence. Thirteenth Meeting. Josiah Macy, Jr. Foundation, 143 to 168, June 10–11, 1946.
[14] Lockhart, C. E., and Elman, R. S. G. and O.: **88:** 97, 1949.
[15] Pareira, M. D., and M. Somogyi: Ann. Surg., **127:** 417, 1948.

[16] Reifenstein, E. C., Jr.: Conference on Metabolic Aspects of Convalescence Including Bone and Wound Healing. Eighth meeting, New York. Oct. 13–14, 1944, page 168.
[17] Somogyi, M.: J. Lab. & Clin. Med., **26:** 1220, 1941.
[18] Stewart, J. D., G. M. Rourke: J. Clin. Investigation, **21:** 197, 1942.
[19] Van Slyke, D. D., and A. Hiller: J. Biol. Chem., **167:** 107, 1947.
[20] Weichselbaum, T. E., and P. L. Varney: Proc. Soc. Exper. Biol. & Med. (In press.)
[21] Weichselbaum, T. E.: Am. J. Clin. Path., **7:** 40, 1946.
[22] White, H. L., and T. Findley: J. Clin. Investigation, **18:** 377, 1939.
[23] Winkler, A. W., J. R. Danowski, J. R. Elkinton and J. P. Peters: J. Clin. Investigation, **23:** 807, 1944.

Discussion.—Dr. Robert Elman, St. Louis, Mo.: In spite of the published warnings of Dr. Coller and many others, it has been my observation that too much intravenous fluid is still being given in many hospitals. I would include in this plasma and whole blood transfusions.

Not only are many of these injections costly and inconvenient, but are too often actually or potentially dangerous. Whenever we use this method of therapy, we therefore have the responsibility of knowing exactly the specific amounts of each element needed for maintaining normal physiological activity.

It was largely for this reason that we are making this preliminary report of the minimum parenteral requirements in patients who for one reason or another take nothing by mouth. I might say that the 96-hour period of observation we used was purely experimental. I don't want to leave the impression that all of our gallbladder patients required parenteral injections during such a long period.

Our objective could be expressed by a very simple dictum, that is, the use of better but less parenteral fluids.

On the basis of the present findings we believe that 2 liters of water and perhaps even a little less in the normal hydrated adult will meet these minimum requirements for water under conditions of the present study.

As to salt intake, we have confirmed the observations of Dr. Lester White, our professor of physiology, and others, that the normal human kidney lags in its excretion for several days whenever presented with salt above the previous level of intake. Since surgical patients often are on simple liquids before operation—and I am excluding those with salt losses due to vomiting, and so on—it is clear that their kidneys may not be able to excrete much salt, so that more will be retained than those on a normal intake up to 9 Gm. a day.

This behavior of the human kidney is quite unlike that of the dog, which excretes added loads of salt rapidly. This difference is one reason among others for the pitfalls which may come from translating data on animals to human beings.

Finally, I would like to point out that our findings on the disturbed utilization of sugar after operation, while perhaps not surprising, may be decisively influenced by the addition of amino acids, a factor which we are now studying separately. This is based upon a few observations made already, which indicate that the addition of amino acids to intravenous glucose in normal humans, at least, seems to increase the utilization of glucose by the tissues.