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ACUTE INTESTINAL OBSTRUCTION

EVALUATION OF RESULTS IN TWENTY-ONE HUNDRED FIFTY CASES; WITH DETAILED STUDIES OF TWENTY-FIVE SHOWING POTASSIUM AS A TOXIC FACTOR

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IN THE Orient, the problem of the neglected case of acute intestinal obstruction is difficult and the mortality high. Even in the United States, despite advances in surgery and a clearer knowledge of many of the altered biochemical reactions, the death rate during the last 15 years has varied little (10.1 to 11.1 per 100,000), but the total number is constantly increasing.[84a]

Mortality rates from as high as 61 per cent[84] to as low as 19 per cent[52] indicate what little uniformity exists regarding treatment and operative procedure. In comparing the results obtained for similar lesions at different hospitals, this disparity becomes especially apparent. For these reasons, Lincoln Davis[98] objected to the evaluation of statistics from various institutions unless they could be compared case by case.

Since the observations of Leichtenstern[64] and Nothnagel,[89] the pulse rate has been used as a criterion in prognosis. In Miller's[84] series, 71 per cent of the fatal cases exhibited either a subnormal temperature, or one above 100° F. A rapid, shallow respiration was stressed by Braun and Boruttau[9] as an ominous sign in obstruction.

In the neglected case, the quick pulse, the rapid respiration and the elevated or subnormal temperature contrast strongly with the normal values found in the early one. In order to test whether a combination of these three variables would give a truer picture of the patient's condition, and thus afford a measure whereby the relative toxic state of each might be gauged, an index combining them was derived and applied in 570 cases of acute intestinal obstruction.[106]

Determination of the Index.—The index is the product of the three variables: Temperature, pulse, and respiration. The normals taken are: Temperature, 98.6° F.; pulse, 72; respiration, 16. To each, an arbitrary value of one is given.

Temperature Factor: For each rise or fall of one degree Fahrenheit, one is added to the normal of one.

Pulse Factor: For every rise of ten in the pulse rate, one is added to the normal of one.

Respiratory Factor: For each rise of five in the respiratory rate, one is added to the normal of one.

Example: A strangulated hernia of three days' duration was admitted with: Temperature, 99.6° F.; pulse, 112; respiration, 26. Index in this case: 2 x 5 x 3 = 30 as compared with Normal Index 1 x 1 x 1 = 1.

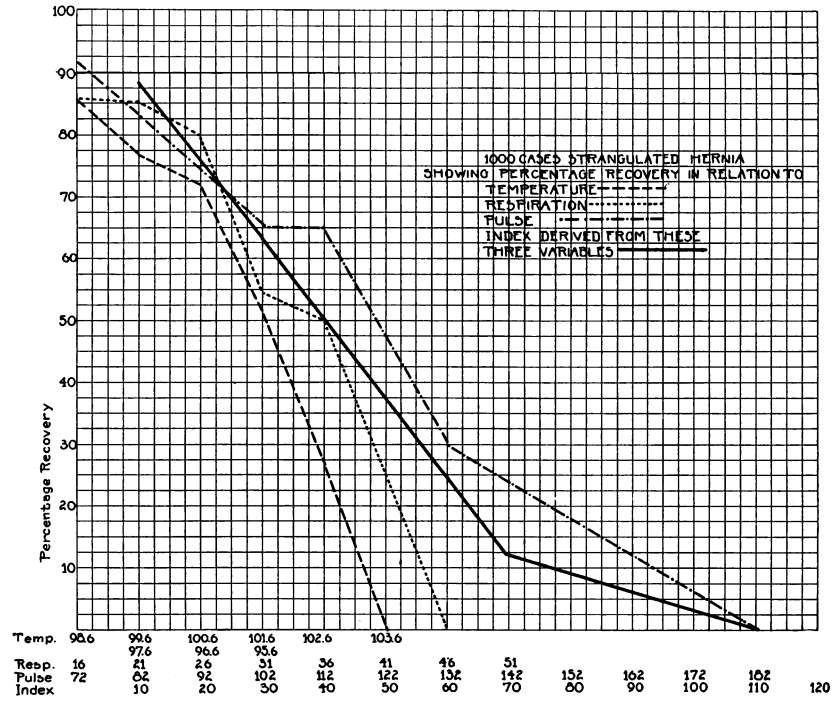


CHART 1.—Ordinates: Temperature, pulse rate and respiration; index. Abscissas: Percentage of recovery.

TABLE I

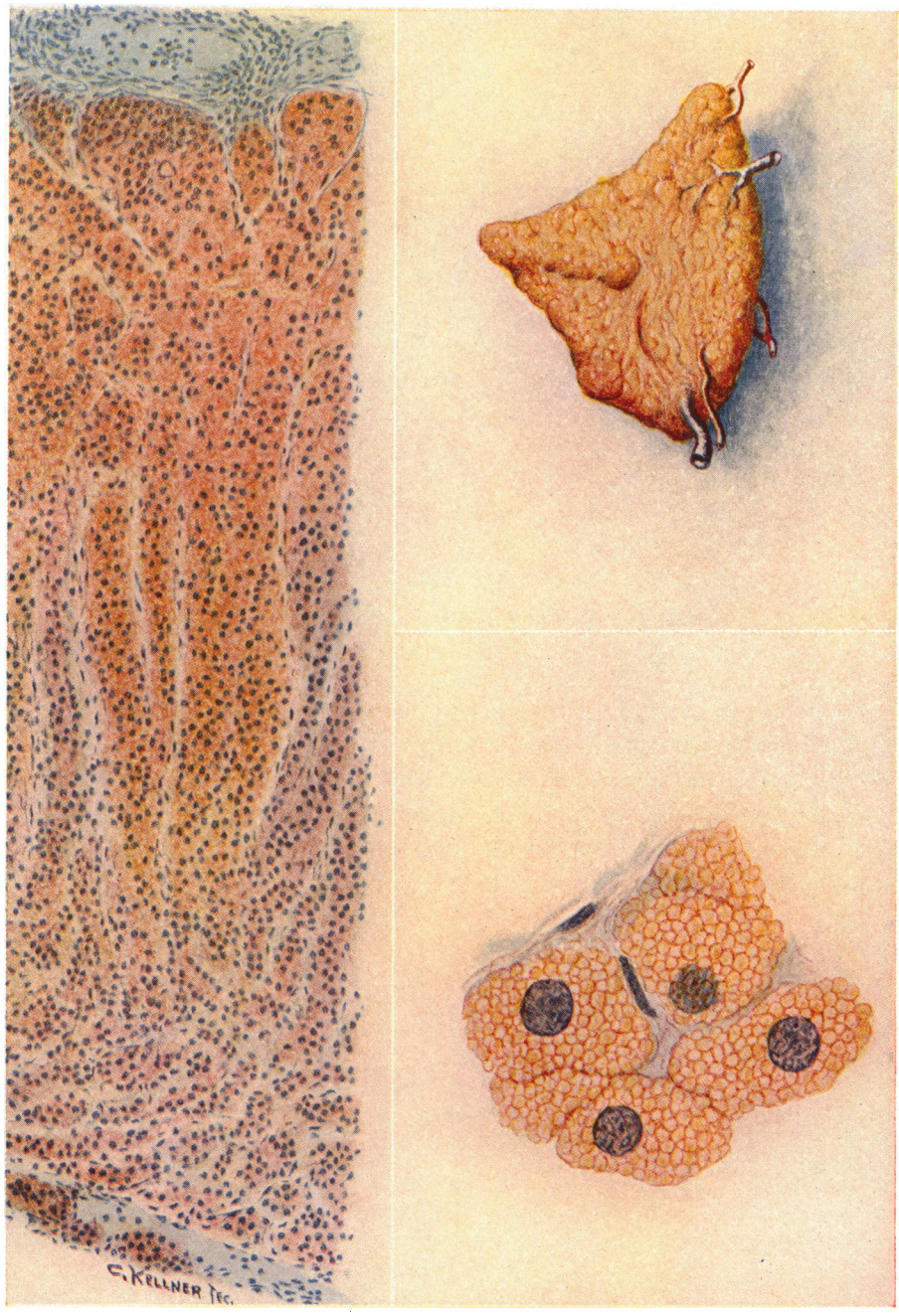
DETERMINATION OF FACTORS

Temperature Factor	Pulse Factor	Respiration Factor
98.6° = 1	72 = 1	16 = 1
97.6°, 99.6° = 2	82 = 2	21 = 2
96.6°, 100.6° = 3	92 = 3	26 = 3
95.6°, 101.6° = 4	102 = 4	31 = 4
102.6° = 5	112 = 5	36 = 5
103.6° = 6	122 = 6	41 = 6

The indices of 1,150 cases of acute mechanical obstruction (Group I*) were determined and charted, with the recovery rate plotted against the index. The declivity of the line shows that survival stands in inverse proportion, and mortality in direct proportion to the magnitude of the index.

PLATE I

NORMAL HUMAN ADRENAL CORTEX



A right adrenal gland of approximately normal size, shape and color showing the superior, middle and inferior arteries, the central vein and an alternate venous drainage (upper right). Camera lucida painting of a segment of a frozen section of adrenal cortex from the capsule (with capsular artery in cross-section) to the juxtamedullary border. The lipoids are stained orange-red with Sudan III, and the nuclei blue with Harris' hematoxylin. The section was mounted in Zwemer's glychrogel. ×120 (left). A few lipoid-rich gland cells from the outer fascicular zone of the above section. A diminution of this type of cell is associated with a demand on the gland. The nuclei of two capillary endothelial cells are also illustrated. ×900. (lower right.)

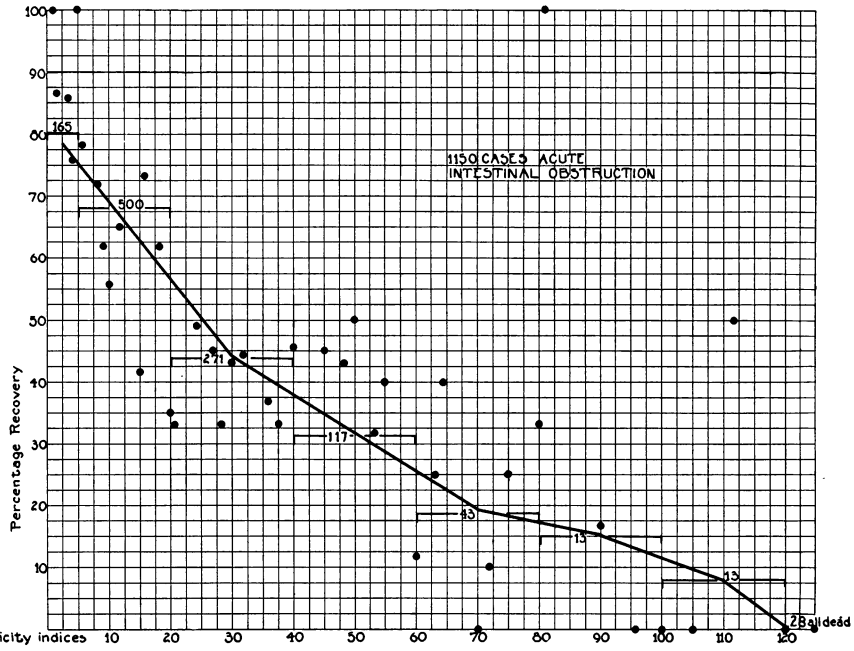


CHART 2.—Ordinates: Toxicity index. Abscissas: Percentage of recovery. Scatter diagram showing the percentage of recovery for each index. Brackets indicate the number of cases and the range of indices taken for each point on the chart.

This same correlation is seen in 1,000 cases of strangulated external hernia (Group III*) (Chart 3).

Analysis of the Results of Operative Procedures.—With the objective value of the index revealed in 2,150 cases† the types of surgical procedures were gauged in respect to the patient's condition.

The reduction of a strangulated hernia with viable intestine gave the optimum prognosis in all cases. The addition of an enterostomy raised the mortality. In the gangrenous hernia, a resection with primary anastomosis augured better than did the principle of marsupialization (Chart 4).

In analyzing the 925 operations with viable intestine, the relief of obstruction, whether effected by division of the adhesions, detorsion of a volvulus, or reduction of an intussusception, offered the patient the best chance as judged by 76 per cent recovery in 520 cases, and a higher survival at each index up to 60 (Chart 5).

A primary enterostomy with the relief of obstruction raised the mortality rate in 149 cases. Grouped as to indices, the recovery rate was lower in those

* Cases of obstruction are grouped according to the Massachusetts General Hospital plan: Group I: Acute mechanical obstruction, except those due to neoplasms. Group II: Obstruction due to neoplasms. Group III: Obstruction due to strangulated external hernia. This paper does not include Group II, nor children under 12 years of age.

† The statistical data were reviewed by Dr. E. B. Wilson of the School of Public Health, Boston. The scatter diagrams were made at his suggestion.

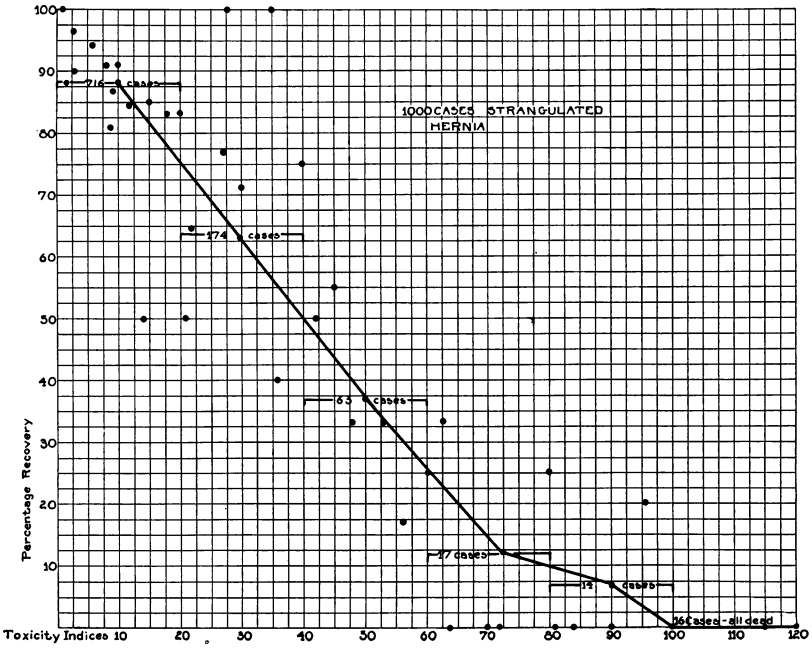


CHART 3.—Ordinates: Toxicity index. Abscissas: Percentage of recovery. Scatter diagram showing percentage of recovery for each index. Brackets indicate the number of cases and the range of indices taken for each point on the chart.

enterostomy cases below 60, and about the same for both the enterostomy and nonenterostomy groups above this index (22 and 19 per cent respectively).

Enterostomy or cecostomy *without* the removal of the lesion gave a 70 per cent mortality, a figure worse than that reported by Treves,[122] in 1884. A short-circuiting operation around the lesion failed to achieve the same success as did its removal.

TABLE II

PERCENTAGE OF RECOVERY IN 2,150 CASES OF ACUTE INTESTINAL OBSTRUCTION, GROUPED ACCORDING TO ETIOLOGY (CHILDREN UNDER 12 EXCLUDED)

GROUP I (Massachusetts General Hospital Classification) Lesion	Lived	Died	Total	Recovery Per Cent
Bands and adhesions	360	213	573	63
Volvulus of small intestine	90	66	156	58
Volvulus of large intestine	70	57	127	55
Intussusception	38	31	69	55
Miscellaneous	18	18	36	50
Gallstones and foreign bodies	8	9	17	47
Meckel's diverticulum	6	9	15	40
Internal strangulated hernia	14	22	36	39
Cause not ascertained	24	62	86	28
Mesenteric thrombosis	4	31	35	11
Totals	632	518	1,150	55
GROUP II Obstruction due to tumors not included.				
GROUP III Strangulated external hernia	765	235	1,000	76.5
Total of Series	1,397	753	2,150	65

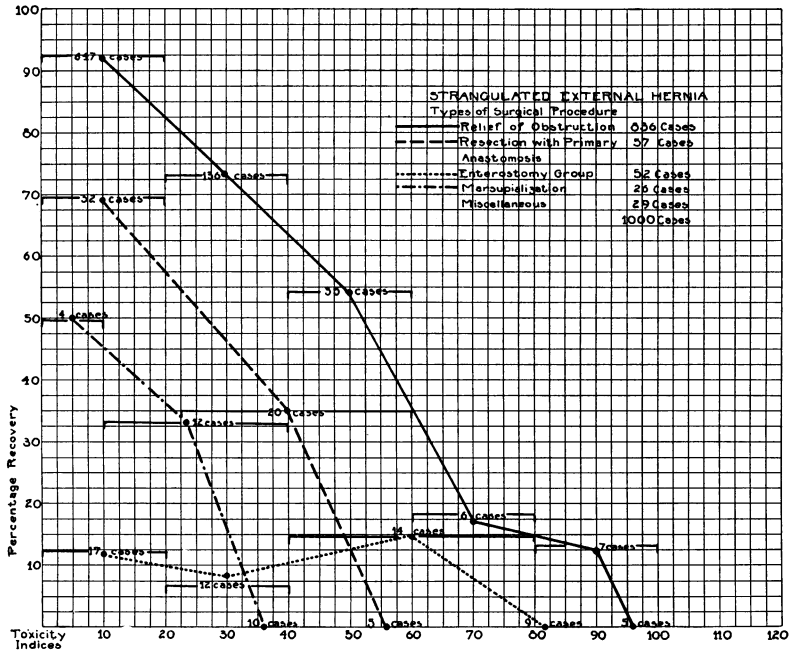


CHART 4.—Ordinates: Toxicity index. Abscissas: Percentage of recovery. Surgical procedures in 1,000 cases of strangulated hernia. Brackets indicate the number of cases and the range of indices for each point on the chart.

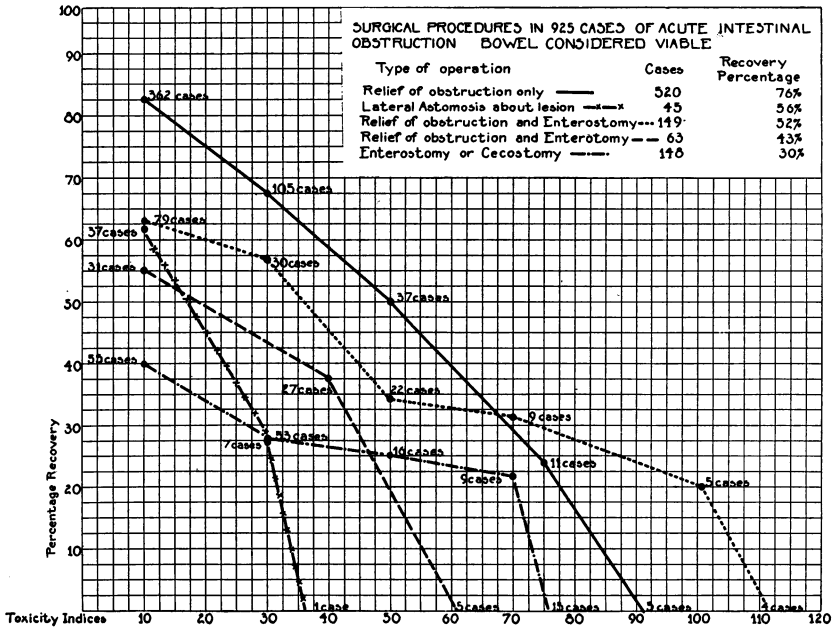


CHART 5.—Ordinates: Toxicity index. Abscissas: Percentage of recovery. Contrast of the recovery rate for different surgical procedures in 925 cases of obstruction. The figures represent the number of cases. For example, there were 362 cases, whose indices ranged from one to 20, in which the obstruction was relieved. The percentage of recovery for this group was 82.5. The next figure, 105, indicates that number of cases whose obstruction was relieved. The indices for this group fell between 21 and 40. The percentage of recovery was 67.5. In the same range of indices there were 30 cases which had the obstruction relieved and a primary enterostomy; their percentage of recovery was 10 per cent less than the 105 cases who did not have a primary enterostomy with the relief of obstruction.

In analyzing the 178 cases with gangrene of the intestine, a resection with a primary anastomosis in the mildly toxic case was preferable, whereas, in the severely ill patient, resection with delayed anastomosis gave better results. Again, the exteriorization of the gangrenous bowel carried the greatest number of failures.

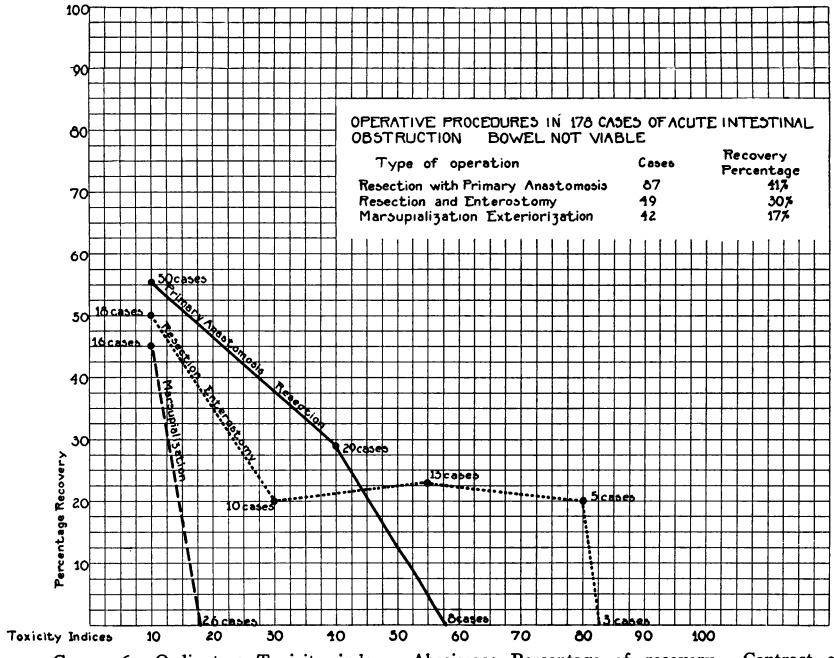


CHART 6.—Ordinates: Toxicity index. Abscissas: Percentage of recovery. Contrast of recovery rate for three different surgical procedures used in dealing with gangrenous intestine. Marsupialization of the loop was not as successful as resection and enterostomy or resection with primary anastomosis.

After summarizing these cases, we are forced to again raise the following questions*: What is the toxic depressor substance in acute intestinal obstruction? Why is strangulation or gangrene more rapidly fatal? In what manner does an enterostomy increase the mortality? Why is gastric lavage beneficial? Why is the slow pulse so often misleading? Finally, how does salt solution mitigate the toxemia of obstruction?

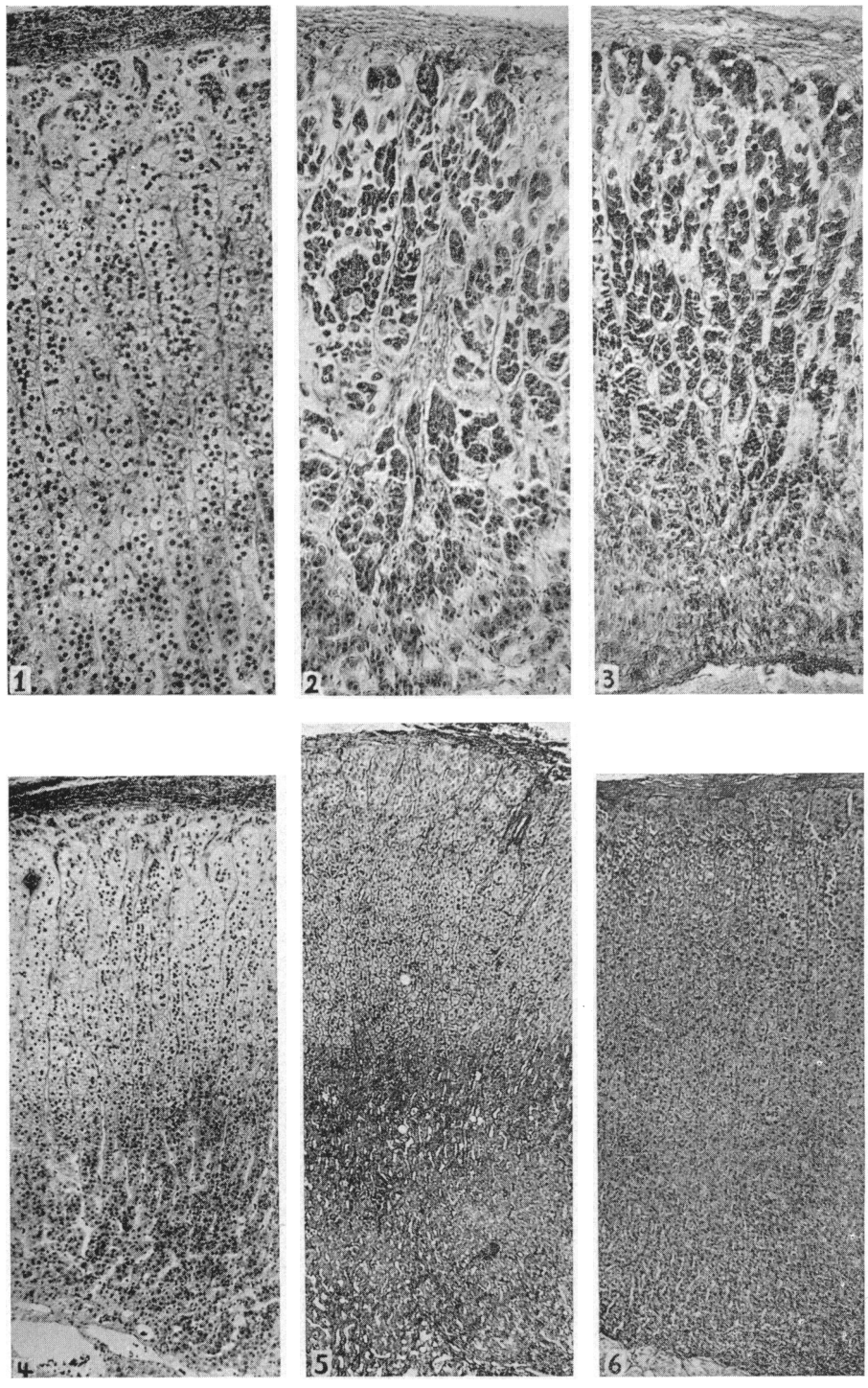
Our attention was directed to the adrenal glands by Wohl, Burns and Clark,[130] who reported cortical cell depletion in experimental obstruction un-

LEGEND FOR PLATE II.—Normal human adrenal cortex. Segment of a median section. Note large clear cells which contained lipoid (×100). Nos. 2 and 3.—Adrenal cortex sections (full width) from two patients dying of intestinal obstruction. Note disorganized cell arrangement and presence of connective tissue between cell columns. It resembles Type 7 or 8 of Zwemer's[133] classification. Postmortem cell changes and shrinkage due perhaps to technic should be discounted (×100). No. 4.—Same adrenal as No. 1 at a lower magnification, to show cell types from capsule to medulla (×60). No. 5.—Normal cat adrenal cortex. The relative thickness of rounded adrenals is greater than that of the folded primate type (×60). No. 6.—Adrenal cortex from Cat No. 3636 showing absence of lipoid-loaded "spongiocytes." This animal died three and one-half days after esophageal obstruction (×60).

* A more complete discussion and bibliography is given by Cooper, H. S. F.: Cause of Death in High Obstruction. Arch. Surg., 17, 918–967, 1928; and by McIver, M. A.: Acute Intestinal Obstruction. New York, Paul B. Hoeber, Inc., 1934.

PLATE II

PHOTOMICROGRAPHS ILLUSTRATING VARIOUS PHASES OF ADRENAL HISTOPATHOLOGY



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treated by saline solutions. Examination of sections secured from autopsy cases at the Peter Bent Brigham Hospital revealed various stages of cortico-adrenal depletion according to the classification of Zwemer.[133]

Acute intestinal obstruction and adrenal insufficiency have many features in common. With the latter a definite disturbance in potassium metabolism has been shown to exist.[1, 7, 42, 49, 69, 137] In experimental obstruction in cats, we have reported a rise in blood potassium to lethal levels. The potassium values for the contents of obstructed loops, peritoneal fluid and vomitus were many times that of blood.[107] In experimental intestinal obstruction in dogs, Cutler and Pijoan[19] confirmed the occurrence of a hyperpotassemia.

Coincident with the experimental work, studies were begun on patients. We report here 25 cases; in 20, potassium determinations were made on blood secured at the time of admission; in two, the blood was taken after the administration of therapy; and in three, after operation.

Methods.—Unless otherwise stated, fasting blood was collected in the morning by the same person. The sample was drawn with a sterile dry syringe from the antecubital vein without a tourniquet and placed into a Sanford-Magath hematocrit tube containing heparin. After centrifuging at 3,000 r.p.m. for one hour, the cell volume was read, and plasma separated immediately from the cells. Samples showing any hemolysis were discarded. The potassium content of 0.1 Ml. of whole blood and 0.4 Ml. of plasma was determined by the method of Truszkowski and Zwemer.[123, 123a] The values given represent the average of two determinations, differing by not more than ± 2 per cent from the mean.

The specific gravity of whole blood and plasma was measured by the falling drop* method of Barbour and Hamilton.[6] Plasma protein was calculated by the formula of Weech, Reeves and Goettsch.[127]

The following figures are given as normal for potassium in the blood of humans: Whole blood, 164 to 200 mg. per cent; serum potassium, 18 to 21 mg. per cent; cells, 350 to 465 mg. per cent, average, 418 mg. per cent. Because of the wide normal range, emphasis should be placed on the change in potassium level rather than in absolute values.[56, 57, 74, 88]

SUMMARY OF THE POTASSIUM CONTENT DATA.—*Plasma Potassium:* In the 20 untreated patients, whose blood was taken on admission, the plasma potassium was raised in seven (Cases 1, 2, 3, 4, 9, 19, 20) and low in five (Cases 5, 8, 14, 16, 18), the highest value being 33.4 mg. per cent (Case 9) and the lowest 13.4 mg. per cent (Case 5). In Case 23, a plasma potassium value of 28.2 mg. per cent was found after 300 cc. of 5 per cent salt solution. Plasma K. decreased in 12 following administration of saline and other treatment.[120] In two (Cases 14 and 22), despite saline, there was an increase in the plasma value. Both cases showed extention of the gangrenous process at autopsy.

Case Report.—Case 20: Bronchopneumonia complicated by a strangulated femoral hernia.[56] Plasma potassium was high, rising to 30.1 mg. per cent following operation;

* Pipettes may be obtained from Eimer & Amend, New York.

decreasing after the administration of eschatin† and salt solution but again climbing to 32.3 mg. per cent in spite of further therapy. Elimination by kidneys poor as indicated by oliguria and a rise in the N.P.N. The K. in the urine, however, was 450 mg. per cent. Profuse sweating and muscular twitchings were prominent features.[108]

Cell Potassium.—In 20 untreated cases the average cell potassium was 359 with a range of 302 to 438 mg. per cent. In 14 of these, cell K. was distinctly low. Treated by injections of salt solutions, cell potassium rose in 12 (Cases 3–9, 11, 13, 14, 15, 18); and fluctuated in Cases 10, 13, 16, 19 and 20. In other conditions the importance of cell K. changes has been stressed.[51, 88a]

Whole Blood Potassium on admission was above normal in five (Cases 5, 6, 7, 12, 13), and low in Case 20.

Peritoneal Fluid Potassium varied from 13.2 to 28.6 mg. per cent in 11 cases.

Spinal Fluid Potassium was lower than the plasma potassium when they were taken simultaneously in Cases 11 and 12.[27]

Potassium Content of Gangrenous Loop Fluid.—The values ranged from 109 to 637 mg. per cent in four cases (Cases 5, 14, 20, and 22). Death occurred in all.

Potassium Content of Enterostomy Fluid.—Analysis of potassium in both plasma and enterostomy fluid in Case 9 showed the results to be identical.[20, 128] In Case 25, the intestinal fluid K. was twice that of plasma.

Potassium Content of Gastric Fluid.—In eight cases (Cases 14, 16, 18, 19, 20, 22, 24 and 25) determinations of potassium in both plasma and gastric contents showed a range in the latter from 18.5 to 65.8 mg. per cent; the average concentration of the gastric juice potassium being 2.5 times that of blood taken simultaneously.[54, 107]

Plasma Specific Gravity.—The average in 18 cases was 1.0297 with a range from 1.0264 to 1.0379. This contrasts with the average normal plasma density of 1.0260 to 1.0270.

Hematocrit.—This showed 48.2 per cent cells in the 20 untreated cases with a range from 33 to 59 per cent. This average of 48.2 per cent contrasts with the normal figure of 45 per cent.

Plasma Protein.—In the untreated cases the average plasma protein was 7.8 Gm. per cent with a range from 6.6 to 10.6 Gm. per cent. This is higher than the average normal of 7.0 Gm. per cent.

DISCUSSION.—Certain phenomena associated with acute intestinal obstruction may be partly explained by considering potassium in their interpretation.

Simple Obstruction.—In the progressive dehydration accompanying this lesion, a lethal rise in blood potassium has been demonstrated experimentally, the rapidity depending upon the site of obstruction.[107]

Intestinal Strangulation and Gangrene.—Interference with the vascular supply of the intestines is always associated with a higher mortality. In our experimental work, we attribute the earlier development of toxemia to a more rapid and sustained rise in blood potassium, occasioned by a loss of fluids,

† Eschatin has been furnished by the kindness of Parke, Davis & Company.

SYNOPSIS OF THE DATA IN 25 CASES OF ACUTE INTESTINAL OBSTRUCTION EXCLUDING THOSE DUE TO NEOPLASMS

Case Number	Hospital Number, Initials, Age, Sex	Type of Lesion. Duration before Operation. Date of Operation. Anesthesia	Date and Time of Obtaining Blood	*Potassium in mg. % in* Whole Blood	Cells	Plasma	Cell Volume by Hematocrit	Plasma Specific Gravity	Plasma Protein	Other Data and Remarks	Result. Date of Discharge
				Average Values for Ten Healthy Donors							
				190	376	16.7	46.1%	1.0261	6.5%		
1.	85728 J. E. 59 yrs. Female	Strangulated incisional hernia. 5 days	9/24/36 2 P.M.	169	343	25.7	42 %	....	....	Ser. chlorides 565 mg.%; Bl. CO_2 61 cc./100; B.U.N. 13 mg./100 Intermittent type of obstruction. Treated conservatively 5 days by colon lavages, clyses of saline and glucose.	
	Index 6	9/29/36 Repair of hernia. G.-O.-E.								Location of lesion: Low ileum	Cured 10/24/36
2.	448691 S. L. 60 yrs. Male	Acute int. obstr. due to bands. 2½ days	9/26/36 11 A.M.	202	366	29.8	47 %	....	....	Case reported previously, ref. SURG., 1, 74, January, 1937.	
			10/17/36 7:30 A.M.	198	367	17.6	49 %	....	....	Location of lesion: Injected loop of lower ileum	
	Index 12	9/26/36 Jejunostomy. Spinal									
		9/28/36 Division of bands. Spinal									Cured 11/5/36
3.	368800 R. P. 37 yrs. Female	Acute int. obstr. due to peritoneal adhesions. 2 days	11/14/36 2 P.M.	196	347	29.1	48 %	1.0287	7.4%	R.B.C. 5,000,000; Hb. 85%; W.B.C. 17,400; P. 89%. Roentgen ray: Multiple fluid levels. Gastric and repeated colon lavages. No improvement in 12 hrs. Clysis 2,000 cc.	
	Index 2	11/15/36 Division of bands. Spinal	11/15/36 3:30 A.M.	180	364	23.0	43 %	1.0246	6 %	Taken after operation Peritoneal fluid was sanguineous.	
			11/16/36 7:10 A.M.	196	390	24.0	44 %	1.0257	6.4%	*Potassium content of centrifuged specimen 21.3 mg.%*	
			11/18/36 7:30 A.M.	157	366	21.5	37 %	1.0231	5.5%	Location of lesion: Cyanotic loop of ileum	Cured 11/29/36
4.	506308 A. C. 47 yrs. Female	Acute int. obstr. due to strangulated ventral hernia. 2 days	12/19/36 1:55 P.M.	207	332	27.3	54 %	1.0299	7.8%	W.B.C. 16,600; P. 85%; Roentgen ray: Fluid levels. Urine: Alb. H.T. Glu. 4+. Acetone 4+. Given 2,000 cc. Ringer's solution by infusion at oper. Peritoneal fluid sanguineous.	
			12/20/36 10:30 A.M.	172	352	20.4	43 %	1.0255	6.3%	*Potassium content after centrifuging 21.3 mg.%*	
		12/19/36 Relief of obstruction. Spinal	12/22/36 7:15 A.M.	154	375	18.9	36 %	1.0246	6 %	12/21/36: Bl. urea N. 21 mg./100 Bl. sugar 144 mg./100 Bl. sugar 153 mg./100	
			12/29/36 7:40 A.M.	174	356	20.9	43 %	1.0275	7 %	Location of lesion: dusky loop of ileum in sac	Cured 1/30/37

5.	506363 M. W. 53 yrs. Female	Anemic infarct of terminal ileum and cecum due to mesenteric thrombosis. 2 days	12/23/36 7:30 P.M.	228	365	13.4	59 %	1.0276	7 %	On admission: W.B.C. 13,500; P. 86%. Given 1,500 cc. of Ringer's solution	
			10 P.M.	233	382	15.0	57 %	1.0301	7.9%	This blood was taken before operation and after the saline had been given	
	Index 100	12/23/36 Resection of cecum and ileum. Primary anastomosis. Spinal	12/24/36 1:30 A.M.	198	334	21.5	53 %	1.0259	6.5%	At the end of operation, during which time 2,000 cc. of Ringer's solution intravenous	
			8 A.M.	220	365	22.8	54 %	1.0262	6.6%	Continuous infusion of Ringer's solution running when this sample was obtained.	
						Serum		Serum	Serum		
			12/25/36 9 A.M.			21.5		1.0234	5.6%	*Potassium content in resected loop after centrifuging: 591.6 mg.%*	
			7 P.M.			20.2		1.0249	6.1%	Location of lesion: Cecum and terminal ileum	
			12/26/36 9 A.M.			24.0		1.0237	5.7%	Autopsy: Extension of mesenteric thrombosis up the ileum	Died 12/26/36
6.	508585 V. F. 31 yrs. Female	Obstruction due to multiple postoperative adhesions.	1/16/37 3 P.M.	210	406	19.9	47 %	1.0303	8 %	On admission: W.B.C. 12,120; P. 95%; Hb. 105. Roentgen ray: "Fluid levels in ileum." Given hyperdermoclysis.	
		1 day	7 P.M.	210	457	18.1	42 %	1.0267	6.7%	This blood taken on operating table after spinal anesthesia and ephedrine had been given.	
	Index 4	1/16/37 Division of adhesions. Spinal	1/17/37 8 A.M.	172	329	20.8	46 %	1.0229	5.4%	*Peritoneal fluid K. 18.4 mg.% uncentrifuged. 17.5 mg.% centrifuged.*	
			1/18/37 8 A.M.	163	388	19.6	37 %	1.0235	5.7%	Location of lesion: Lower ileum	Cured 2/1/37
7.	508670 G. L. 70 yrs. Male	Obstruction due to strangulated inguinal hernia. Richter's hernia of transverse colon.	1/20/37 9 P.M.	210	352	19.7	54 %	1.0272	6.9%	W.B.C. 14,600; P. 94%. Roentgen ray: Fluid levels. Barium enema showed obstruction in transverse colon	
			1/21/37 2 A.M.	192	332	19.6	52 %	1.0264	6.6%		
	Index 24	1 day								Taken during operation but before 3,000 cc. of Ringer's solution had been given by infusion and clysis	
		1/21/37 Relief of obstruction. Spinal	7:30 A.M.	184	340	17.5	49 %	1.0261	6.5%	Taken before clysis of 2,000 cc. of saline and glucose	
			1/22/37 7:30 A.M.	170	318	20.4	47 %	1.0242	5.9%	Taken before clysis of 1,500 cc. of saline and 5% glucose	
	–		2/3/37 7:30 A.M.	178	318	18.4	50 %	1.0275	7 %	Location of lesion: Transverse colon	Cured 2/6/37

(Continued on next page)

SYNOPSIS OF DATA (*continued*)

Case Number	Hospital Number, Initials, Age, Sex	Type of Lesion. Duration before Operation. Date of Operation. Anesthesia	Date and Time of Obtaining Blood	*Potassium in mg. % in* Whole Blood	Cells	Plasma	Cell Volume by Hematocrit	Plasma Specific Gravity	Plasma Protein	Other Data and Remarks	Result. Date of Discharge
8.	509097 W. C. H. 34 yrs. Male	Obstruction due to multiple postoperative adhesions. 2 days	2/8/37 1:30 P.M.	180	350	15.2	47 %	1.0304	8 %	W.B.C. 15,200; P. 88%.	
			6:55 P.M.	180	374	15.4	44 %	1.0289	7.5%	Taken after operation and before infusion of Ringer's solution	
	Index 18	2/8/37 Division of peritoneal bands. Spinal	8 P.M.	150	320	12.9	43 %	1.0258	6.4%	Taken after infusion	
			2/17/37 7:30 A.M.	137	335	19.8	35 %	1.0262	6.6%	Location of lesion: Lower ileum	Cured 2/23/37
9.	419165 L. P. Negro 29 yrs. Male	Obstruction due to band. Had been operated on for acute appendicitis with peritonitis 2½ yrs. previously.	2/17/37 4:45 P.M.	195	306	33.4	53 %	1.0379	10.6%	N.P.N. 55 mg.%; W.B.C. 18,700; P. 88%. Roentgen ray: "Fluid levels in ileum." B.P. 140/110	
			9:40 P.M.	201	334	23.7	53 %	1.0379	10.6%	Taken on operating table after spinal and ephedrine had been given and after incision	
	Index 12	4 days	10:40 P.M.	183	330	18.3	50 %	1.0341	9.3%	Taken at the end of operation and after the administration of 1,500 cc. of Ringer's solution by infusion	
		2/17/37 Division of band. Enterostomy. Spinal G–O–E.	2/18/37 8:10 A.M.	182	354	15.8	47 %	1.0238	5.8%	*Peritoneal fluid cloudy. Potassium content 15.9 mg.%* Continuous infusion running when blood was taken. Serum chlorides 585 mg.% Bl. urea N. 23 mg.%	
			2/19/37 7:30 A.M.	179	342	21.2	46 %	1.0283	7.3%	Continuous infusion running. Gastric suction stopped today. Enterostomy draining. *Potassium of enterostomy fluid 21.2 mg.%.* R.B.C. 4,900,000; Hb. 85%	
			2/20/37 7:30 A.M.	195	386	17.6	46 %	1.0258	6.4%	*Potassium of enterostomy fluid 18.0 mg.%*	
			2/24/37 7:30 A.M.	177	359	22.7	43 %	1.0264	6.6%	Ser. chlorides 515 mg.%; CO_2 56 Ml./100. cc. Enterostomy tube still draining	
			3/6/37 7:30 A.M.	176	382	16.0	42 %	1.0242	5.9%	Wounds practically healed. Up in chair Location of lesion: Lower ileum	Cured 3/12/37
10.	258815 G. L. 35 yrs. Negress	Obstruction due "large inflamed sheath of tissue where the broad ligament had been united at a pre-	2/19/37 2:30 P.M.	163.4	438	19.1	33 %	1.0318	8.5%	R.B.C 4,120,000; Hb. 70%; W.B.C. 7,900; P. 58%; N.P.N. 28.7 mg.%; ser. chlorides 563 mg.%. Roentgen ray: "Gaseous distended loops of colon with multiple fluid levels"	

	Index 10	vious operation 27 days ago." 2 days	2/20/37 7:30 A.M.	146	286	23.2	43 %	1.0267	6.7%	Colostomy has not been opened. Patient very restless. Pulse 160; temp. 104°. Has had 3,000 cc. of saline and 5% glucose by clysis and infusion	
		2/19/37 Colostomy. Spinal	3/17/37 7:45 A.M.	182	486	21.3	33 %	1.0276	7 %	Up in chair today. Colostomy functioning Location of lesion: Sigmoid To return for closure of colostomy later	Relieved 4/5/37
11.	512603 B. C. 70 yrs. Female	Obstruction due to strangulated femoral hernia. 2 days	3/9/37 4:50 P.M.	190	348	19.7	49 %	1.0294	7.7%	W.B.C. 12,700; P. 89%; B.P. 150/100. Before operation given 1,500 cc. of 5% glucose in Ringer's solution. Ser. chlorides 565 mg.%; Bl. CO_2 50 Ml./100 cc. *Potassium content of spinal fluid 15.3 mg.%.*	
	Index 6	3/9/37 Reduction of strangulated hernia with imbrication.	9 P.M.	184	342	19.4	48 %	1.0295	7.7%	At the end of operation. *Potassium content of peritoneal fluid 12.5 mg.%*	
		Spinal	3/14/37 8:15 A.M.	189	450	13.2	39 %	1.0257	6.4%	Has had 80 Gm. of NaCl and 14,000 cc. of fluid since last blood sample	Cured 3/27/37
12.	399137 J. R. 72 yrs. Male	Strangulated left indirect inguinal hernia	4/14/37 4:15 P.M.	222	373	20.4	54 %	1.0304	8 %	Admitted to medical ward. Diagnosis: Coronary? W.B.C. 14,950; P. 87%; R.B.C. 6,840,000; Hb. 105%. Sp. gr. of blood: 1.0598; B.P. 120/80. Electrocardiogram:	
			7:25 P.M.	233	421	17.5	51 %	1.0286	7.4%	T wave changes either due to myocardial damage or digitalis medication. Has had	
	Index 24	2 days	4/15/37 8 A.M.	250	487	16.1	49 %	1.0278	7.1%	2,000 cc. of saline and 5% glucose by clysis. Second blood taken after spinal	
		4/14/37	4/16/37 8 A.M.	222	427	15.7	48.5%	1.0291	7.6%	and before infusion	
		Reduction of strangulation; repair of hernia	4/17/37 8 A.M.	216	404	14.3	50 %	1.0280	7.2%	*Potassium content of peritoneal fluid 28.6 mg.%*	
			4/19/37 8 A.M.	205	383	15.7	49.5%	1.0288	7.5%	*Potassium content of spinal fluid at operation 14.7 mg.%*	
		Spinal								Stay in hospital prolonged due to acute cystitis following retention of urine due to benign hypertrophy of prostate. Location of lesion: Ileum	Cured 5/10/37
13.	516211 M. B. 65 yrs. Male	Strangulated rt. direct inguinal hernia 6 hrs. 4/27/37	4/27/37 2:15 P.M.	226	427	20.4	48 %	1.0287	7.4%	No saline given before operation. B.P. 170/98. 1,500 cc. of saline given by clysis postoper.	
			4/28/37 8 A.M.	172	356	18.6	43 %	1.0250	6.2%		
	Index 8	Relief of strangulation; repair of hernia	4/30/37 8 A.M.	175	420	14.5	38 %	....	....	Has had 6,000 cc. of saline by clysis since last blood analysis	
			5/1/37 8:30 A.M.	161	360	15.2	40.5%	1.0237	5.7%	Has had 1,500 cc. of saline by clysis since last blood analysis	

(*Continued on next page*)

SYNOPSIS OF DATA (*continued*)

Case Number	Hospital Number, Initials, Age, Sex	Type of Lesion. Duration before Operation. Date of Operation. Anesthesia	Date and Time of Obtaining Blood	*Potassium in mg.% in* Whole Blood	Cells	Plasma	Cell Volume by Hematocrit	Plasma Specific Gravity	Plasma Protein	Other Data and Remarks	Result. Date of Discharge
		Spinal	5/6/37 7:50 A.M.	229	484	17.2	44.1%	1.0266	6.7%	Developed bronchopneumonia May 2	
			5/7/37	182	344	18.1	47.5%	1.0262	6.6%	Temperature normal. Location of lesion: Low ileum	Cured 5/20/37
14.	312208 J. S. G. 42 yrs. Female	Strangulated postoperative ventral hernia	5/15/37 1:40 P.M.	185	383	16.9	43.9%	1.0298	7.8%	W.B.C. 12,250; P. 88%; N.P.N. 43 mg.%; CO_2, 64 Ml./100 cc.. Specific gravity of whole blood 1.0583. B.P. 118/70. *Potassium content of peritoneal fluid 18.5 mg.%*	
			4:30P.M.	202	424	15.4	44 %	1.0307	8.1%	Sample taken during operation before infusion. Culture of peritoneal cavity: *B. coli.*	
		2 days	6:30 P.M.	186	390	17.4	43.3%	1.0265	6.6%	At end of operation after infusion 1,000 cc. saline but before transfusion of whole blood. *Potassium content of gangrenous gut 637 mg.%*	
		5/15/37	6:50 P.M.	191	368	19.0	46.6%	....	....	After transfusion of 500 cc. of blood	
	Index: no data	Resection of gangrenous ileum: primary end-to-end anastomosis G.-O.-E.	5/16/37 7:50 A.M.	183	387	20.7	41.8%	1.0261	6.5%	Has had 2,000 cc. of saline intravenously since last analysis. Nasal suction by Wangensteen tube all night. *Potassium content of gastric fluid 42.4 mg.%.*	
		Autopsy: Bilateral bronchopneumonia. Extension of gangrene of ileum. Leakage of site of anastomosis with peritonitis. Infection of wound	5/17/37 7:50 A.M.	158	390	12.5	37.5%	1.0259	6.4%	Has had 3,000 cc. of saline intravenously since last analysis. Total amount of NaCl since admission 67 Gm. Signs of pneumonia. Temp. 102°	
			5/18/37 7:50 A.M.	174	447	13.5	35.9%	1.0266	6.7%	Has had 2,500 cc. more saline intravenously by continuous drip. Ser. chlorides 624 mg.%. Blood urea nitrogen 9 mg.%;	
		Note: At operation the strangulated loop had ruptured; local peritonitis	3:05 P.M.	145	366	13.2	36 %	1.0257	6.4%	CO_2 39 Ml./100 cc., before transfusion	
			4:10 P.M.	170	394	16.3	39 %	1.0258	6.4%	10 min. after transfusion of 500 cc. of blood. Placed in oxygen tent	
			5/21/37 8:20 A.M.	148	347	13.0	39 %	1.0261	6.5%	Ser. chlorides 672 mg.%. Blood urea N. 7 mg.%; CO_2 49 Ml./100 cc. Blood culture: No growth. Temp. 106°, pulse 140, resp. 36	
			4:40 P.M.	186	384	13.8	44.7%	1.0267	6.7%	This sample taken after transfusion and 16 hrs. before death. The patient went into shock the following morning and died with temp. of 107.2°. Location of lesion: Terminal ileum	Died 5/22/37

15.	445205 G. R. 68 yrs. Male	Strangulated rt. femoral hernia	5/20/37 1 P.M.	178	336	21.3	46.6%	1.0289	7.5%	No saline given before operation. B.P. 178/80. This sample obtained on operating table before infusion	
		1 day	5/21/37 8 A.M.	228	480	16.5	44.2%	1.0238	5.8%	Has had 2,000 cc. of saline since last blood sample	
	Index: No data	5/20/37 Relief of strangulation; repair of hernia Local	5/24/37	188	332	17.3	51.6%	1.0271	6.9%	Nonprotein nitrogen 47 mg.%. Doing well Location of lesion: Ileum	Cured 6/4/37
16.	436642 R. G. 39 yrs. Female	Obstruction due to postoperative adhesions about which there was a volvulus Hysterectomy 1934	5/21/37 1 P.M.	180	335	15.9	49 %	1.0310	8.2%	W.B.C. 10,200; P. 77%. Roentgen ray: Fluid levels in ileum. Sp. gr. blood 1.0624. CO_2 combining power 75.3%; N.P.N. 37 mg.% Infusion of saline and 5% glucose given before operation.	
		5 days	6 P.M.	166.7	346	13.5	44.4%	1.0274	7 %	Blood sample taken on operating table after infusion. Second infusion 1,000 cc. saline and 300 cc. 5% NaCl. *Potassium content of peritoneal fluid 13.2 mg.%*	
	Index 12	5/21/37 Division of peritoneal bands. Ileotomy	5/22/37 7:30 A.M.	145	332	15.4	39 %	1.0266	6.7%	Ser. chlorides 624 mg.%. Blood urea nitrogen 16 mg.%. CO_2 51 Ml./100 cc. Continuous infusion and gastric suction since operation. *Potassium content of gastric fluid 65.8 mg.%* Has had 4,560 cc. of saline since admission	
		Spinal	5/23/37 7:40 A.M.	134.2	320	13.1	38 %	1.0260	6.5%	Has had 2,000 cc. more of saline intravenously. Gastric suction stopped last night	
			5/24/37 7:20 A.M.	121	324	14.1	32.9%	1.0245	6 %	R.B.C. 3,820,000; Hb. 61%; W.B.C. 5,200; P. 73%. Given transfusion	
			5/27/37 8 A.M.	147	328	25.3	37.2%	1.0261	6.5%	Location of lesion: Low ileum	
			6/3/37 8:30 A.M.	166	382	19.4	38.5%	....	....		Cured 6/19/37
17.	524151 M. McD. 46 yrs. Female	Obstruction due to incisional hernia. Distention 4 hrs. Attacks of cramp-like pain 1 wk.	8/2/37 9:15 P.M.	192	373	20.1	46 %	1.0272	6.9%	Obese, florid patient. Given spinal anesthesia. Died on table. B.P. 200/98 before operation. Patient was extremely nervous and apprehensive. Gas-oxygen administered before spinal puncture. Became cyanotic. On admission, sp. gr. of blood 1.0572. W.B.C. 9,600; P. 63%. Urine: Glucose 4+, alb. 1+	
	Index 2 8/2/37 Spinal										Died 8/2/37

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SYNOPSIS OF DATA (*continued*)

Case Number	Hospital Number, Initials, Age, Sex	Type of Lesion. Duration before Operation. Date of Operation. Anesthesia	Date and Time of Obtaining Blood	*Potassium in mg. % in* Whole Blood	Cells	Plasma	Cell Volume by Hematocrit	Plasma Specific Gravity	Plasma Protein	Other Data and Remarks	Result. Date of Discharge
18.	456262 F. L. 59 yrs. Female	Obstruction due to strangulated umbilical hernia.	9/16/37 12:10 A.M.	162	302	15.3	48.4%	1.0264	6.6%	Sp. gr. whole blood 1.0556. CO_2 36 vol.%. Ser. chlorides 496 mg.%. Bl. sug. 386 mg. %. After 1,000 cc. of infusion R.B.C. 4,400,000; Hb. 96%; W.B.C. 11,600; P. 88%	
		1½ days	1:15 A.M.	192.3	387	17.2	45.4%	1.0239	5.8%	Preop. sample after infusion	
	Index 20	9/16/37	7:50 A.M.	139.4	296	12.3	43 %	1.0235	5.7%	CO_2 39 vol. %. Bl. urea N. 19 mg.%; bl. sug. 316 mg.% *Potassium content of gastric suction 34.2 mg.%*	
		Reduction of hernia with repair	1:45 P.M.	167	378	12.1	40.9%	1.0222	5.2%	Before transfusion of 500 cc. of blood: Sug. 153 mg.%	
			2:45 P.M.	167	366	12.3	42.1%	1.0232	5.5%	5 min. after transfusion: Ser. chlorides 560 mg.%. Given 2,000 cc. of Hartmann's solution	
		Local	9/17/37 8:30 A.M.	165	352	11.2	43.6%	1.0225	5.3%	CO_2: 49 vol.%. Ser. chlorides 542 mg.%. Bl. sug. 124 mg.%	
			9/18/37 8 A.M.	172	371	10.4	43.6%	1.0222	5.2%	CO_2: 56 vol.%. Ser. chlorides 542 mg.%	
			10/9/37 7:40 A.M.	191	386	16.2	45.2%	1.0263	6.6%	Blood sug. 117; diabetes controlled. C. 100. P. 60-F. 50. 35 units of protamine insulin	Cured 10/21/37
19.	530547 L. H. 40 yrs. Female	Obstruction due to strangulated femoral hernia	9/30/37 5:30 P.M.	225	371	23.5	54.4%	1.0305	8 %	W.B.C. 22,500; P. 93%; R.B.C. 6,930,000; Hb. 128%. Sp. gr. of blood 1.0600. Given 2,000 cc. of Ringer's. Urine: Alb. 0, acetone 0. *Potassium in vomitus 46.1 mg.%*	
		19 hrs. 9/30/37	8 P.M.	186	368	16.5	46 %	1.0290	7.5%	Before operation but after infusion. Gastric suction started after operation. Given second infusion postop. of 1,500 cc. of Ringer's	
	Index 45	Reduction of hernia, with repair	10/1/37 7:50 A.M.	153	340	14.7	40.8%	1.0230	5.5%	CO_2 44 vol.%. Ser. chlorides 644 mg.%. Given two clyses 3,000 cc. of dextrose and Ringer's *Potassium content of peritoneal fluid 17.2 mg.%*	
		Spinal	10/2/37 6:30 A.M.	147	282	21.3	44.5%	1.0267	6.7%	CO_2 43 vol.%. Ser. chlorides 592.	
			10/8/37 8 A.M.	150	347	18.3	38 %	1.0252	6.2%	Oct. 6, Bl. urea N. 6 mg.% Smooth postoperative course.	
			10/25/37 8:30 A.M.	174	382	17.2	41 %	1.0255	6.3%	Location of lesion: Low ileum	Cured 10/25/37

20.	408044 F. O. 52 yrs. Male	Obstruction due to strangulated femoral hernia. Cramp-like pain 65 hrs. Vomiting 3 hrs.	10/1/37 3:10 P.M.	157	321	27.8	40.2%	1.0293	7.6%	Patient with mitral and aortic stenosis and insufficiency admitted for bronchopneumonia Type III. Developed hernia due to excessive coughing. Bl. chlor. 572 mg.%. CO_2 70 vol.%; B.P., 4 hrs. postop. 115/85.
			6:30 P.M.	158	287	30.1	44.5%	1.0268	6.8%	Sample taken after operation. Patient placed in oxygen room. Given infusion 1,500 cc. of Ringer's and 20 cc. of eschatin. Venous pressure before infusion 72 Mm.
	Index 72	10/1/37 Resection of gangrenous Richter's type of hernia. End-to-end anastomosis. Local and avertin	10/2/37 4:45 A.M.	..	..	21.3	37.8%	1.0283	7.3%	Went into shock 6 hrs. postop. 50% glucose intravenously plus 20 cc. of eschatin and indirect transfusion 300 cc. Profuse sweating. B.P. 40/0. Pulse 170. Gastric suction functioned well. Abd. soft. Infusion continued with 5% glucose and normal saline. 40 cc. of eschatin, N.P.N. 51 mg.%; ser. chlorides 614 mg.%; CO_2 50 vol.% 7 A.M. N.P.N. 77 mg.%; ser. chlorides 600 mg.%; CO_2 50 vol.% 7 P.M. During 20 hrs. before death, the twitching of various muscle groups with carpopedal spasm on applying tourniquet was very striking. 24 cc. of digalen and two injections of 50% sucrose during 12 hrs.
			7:15 A.M.	151	322	26.2	38.8%	1.0291	7.5%	
			2:15 P.M.	154	319	32.3	38.1%	1.0289	7.5%	
			7 P.M.	156	339	31.1	36.8%	1.0282	7.2%	
			Autopsy: Rheumatic endocarditis of mitral and aortic valves. Mitral stenosis and insufficiency. Aortic stenosis and insufficiency. Cardiac hypertrophy and dilatation. Lobular pneumonia. Chronic passive congestion of lungs. Peritoneal abscess localized. Amebic abscess of liver, obsolete. Fibrous pleural and peritoneal adhesions							*Potassium content of resected loop fluid 109 mg.%* *Potassium content of gastric suction fluid 38.1 mg.%* *Potassium content of urine 450 mg.%* Location of lesion: Low ileum (See chart for further details)
										Died 10/2/37

FIVE CASES IN WHOM THE INITIAL BLOOD WAS TAKEN AFTER TREATMENT OR OPERATION

21.	463986 B. S. 17 yrs. Female	Obstruction due to postoperative adhesions. 4½ days	2/8/37 3:20 P.M.	161	351	15.1	41.5%	1.0227	5.4%	Patient admitted 2/5/37 with tentative diagnosis of acute cholecystitis. Under observation for 3 days during which time she received two infusions of saline and 5% glucose and 1,000 cc. of Ringer's solution by clysis. The initial potassium determination done on blood taken before operation. Roentgen ray: Fluid levels.
	Index on admission: 8. Before operation: 8	2/8/37 Division of adhesions. G.-O.-E.	7:40 P.M.	187	360	14.5	48 %	1.0232	5.5%	Taken at the close of operation
			2/10/37 4:15 P.M.	148	309	17.9	42 %	1.0211	4.8%	*Potassium in peritoneal fluid 16.3 mg.%* Roentgen ray: Pneumonia of rt. lung. Has had 5,000 cc. of saline by infusion and clysis since last blood determination. Gastric suction for two days
			2/24/37 7:40 A.M.	172	374	18.1	41 %	....	....	Location of lesion: Lower ileum Cured 2/24/37

(Continued on next page)

SYNOPSIS OF DATA (*continued*)

Case Number	Hospital Number. Initials, Age, Sex	Type of Lesion. Duration before Operation. Date of Operation. Anesthesia	Date and Time of Obtaining Blood	*Potassium in mg. % in* Whole Blood	Cells	Plasma	Cell Volume by Hematocrit	Plasma Specific Gravity	Plasma Protein	Other Data and Remarks	Result. Date of Discharge
22.	359290 J. W. 64 yrs. Female	Obstruction due to postoperative adhesion causing gangrene of jejunum.	1/7/37							Admitted with diagnosis of obstruction due to impacted feces in colostomy stoma R.B.C. 5,010,000; Hb. 95%; W.B.C. 27,760; P. 95% *Potassium content of fluid above obstruction 147 mg. %*	
	Index on admission: 16. Before operation: 63	24 hrs. 1/8/37 Resection of jejunum, end-to-end anastomosis. Contamination due to spilling of intestinal contents.	1/8/37 9:30 A.M.	172	400	16.6	39 %	1.0267	6.7%	This blood was taken at the end of operation and after the patient had received 4,800 cc. of Ringer's solution and 5% glucose *Potassium content of gastric suction 52.3 mg. %*	
			11:45 A.M.	174	384	16.3	41 %	1.0243	5.9%	Before transfusion	
		Wound left open and treated with zinc peroxide.	12:05 P.M.	178	366	20.6	43 %	1.0261	6.5%	After transfusion 600 cc. of whole blood	
		Spinal	1/9/37 7:30 A.M.	179	370	19.7	43 %	1.0246	6 %	Continuous infusion running. B.U.N. 21 mg. % *Potassium content of gastric suction: 61.6 mg.%*	
			1/11/37 8 A.M.	166	420	14.9	36 %	1.0236	5.7%	Has had 10,000 cc. of saline since last sample *Potassium content of gastric suction 35.1 mg.%* R.B.C. 3,820,000; Hb. 68%	
		Wound culture: Hem. and nonhem. strep. Gram-positive rods. *B. coli*	1/12/37 4 P.M.	152	403	15.1	34 %	1.0239	5.8%	Before transfusion *Potassium content of gastric suction 19.5 mg.%*	
			4:20 P.M.	160	395	21.1	35 %	1.0293	7.6%	After transfusion of 500 cc. of whole blood	
			1/14/37 8:20 A.M.	163	410	15.5	36 %	1.0223	5.2%	Gastric suction and continuous infusion discontinued.	
			1/15/37 8:30 A.M.	142	315	12.3	41 %	1.0284	7.3%	Running a temperature of about 2 degrees; sloughs separating from wound	
			1/18/37 8 A.M.	134	360	10.0	34.5%	1.0267	6.7%	January 19. R.B.C. 3,500,000; Hb. 52%	
			1/20/37 8 A.M.	115	312	8.7	34 %	1.0240	5.8%	Running septic temperature	
			1/23/37 3:30 P.M.	125	454	16.2	24 %	1.0247	6 %	Before transfusion	

			4 P.M.	114	321	17.5	30 %	1.0258	6.4%	5 minutes after transfusion of 600 cc. of whole blood
			1/28/37							R.B.C. 2,700,000; Hb. 42%; W.B.C. 17,300; P. 85%. Serum chlorides 566 mg.%; blood urea N. 88 mg.%
			1/29/37							Given transfusion of 800 cc. of whole blood. One hour later suddenly became cyanotic and died 3½ hrs. later. Death attributed to possible anaphylactic reaction Location of lesion: Jejunum Died 1/29/37
23.	433160 W. P. 80 yrs. Male Index: 20	Obstruction due to multiple peritoneal adhesions. 4 days 2/2/37 Division of peritoneal adhesions. Enterostomy. Spinal	2/2/37	....	....	....	....	Specific gravity of whole blood.	....	W.B.C. 15,100; P. 75%. Roentgen ray: Multiple fluid levels. Given 4,000 cc. of saline and 5% glucose by clysis. Went into shock 10 hrs. after operation
			2/3/37 4:20 P.M.	191	325	28.2	50 %	1.0597 (4:10 P.M.) 1.0500 (4:20 P.M.)		Venous pressure 65 Mm. of water at 3:30 P.M. No blood could be obtained from the vein as the patient was in collapse. 300 cc. of 5% NaCl administered after which the blood was secured for analysis. This blood obtained after 300 cc. more of 5% saline.
			4:45 P.M.	182	352	23.9	45 %			
			6:40 P.M.	....	....	....	....	1.0567		Venous pressure 140 Mm. of water at start of transfusion. After 200 cc. of blood, 120 Mm. of water. After 200 cc. more of blood, 175 Mm. of water. Hence no more blood given. Died 9 hrs. later Autopsy: Peritonitis Location of lesion: Middle and lower ileum Died 2/4/37
24.	514139 L. A. D. 64 yrs. Male	Strangulated femoral hernia. Richter's type. 2 days 4/8/37 Resection of small intestine, with primary anastomosis. Spinal								W.B.C. 9,700; P. 82% with "shift to left." Roentgen ray: Fluid levels. By the time the first blood analysis was made the patient had received: 17,000 cc. of saline solution by infusion and clysis. Equivalent to 168 Gm. of salt. Bl. Urea N. 4/10/37, 27 mg.%. Gastric suction maintained 4 days postoper. Serum chlorides 700 mg.%; CO_2 48 Ml./100. Given transfusion of 600 cc. of whole blood at 11:30 A.M. This analysis before procedure. *Potassium in gastric contents 45.0 mg.%*
			4/12/37 9:30 A.M.	192	490	15.5	36 %	1.0232	5.5%	
			11:20 A.M.	202	509	16.3	36.5%	1.0238	5.7%	
			11:45 A.M.	195	448	15.6	40 %	1.0262	6.6%	Blood sample taken after transfusion. Placed in oxygen tent. Roentgen ray: "Confluent bronchopneumonia both lungs." Blood culture neg.
			4/14/37 8:30 A.M.	222	482	15.1	43 %	1.0229	5.4%	Fluid intake since admission: 26,400 cc. Bilateral pitting edema of legs. Blood urea N. 13 mg.%. Parenteral fluids stopped.

(*Continued on next page*)

SYNOPSIS OF DATA (*continued*)

Case Number	Hospital Number. Initials, Age, Sex	Type of Lesion. Duration before Operation. Date of Operation. Anesthesia	Date and Time of Obtaining Blood	*Potassium in mg. % in* Whole Blood	Cells	Plasma	Cell Volume by Hematocrit	Plasma Specific Gravity	Plasma Protein	Other Data and Remarks	Result. Date of Discharge
										Urine: Sp.gr. 1.035, neg. for alb., gluc. R.B.C. 4,960,000; Hb. 95% (April 16)	
			4/17/37 8:30 A.M.	170	352	11.5	45 %	1.0240	5.8%	Edema of lower extremities less. Still in oxygen tent. Removed from tent in afternoon	
			4/22/37 8:15 A.M.	202	376	21.4	48 %	1.0233	5.6%	Afebrile today. On regular diet. Blood sample taken 10 min. after breakfast	
			5/6/37 8 A.M.	172	430	18.8	35.6%	1.0244	6 %	Discharged home today. Location of lesion: Middle ileum?	Cured 5/6/37
25.	527974 V. W. 16 yrs. Female	Volvulus of small intestine. 36 hrs.								Admitted for recurrent attacks of abdominal, cramp-like pain, vomiting and distention with diagnosis of appendicitis. Appendicectomy August 5, 1937. Normal	
	Index: 30	8/9/37 Jejunostomy after reduction of volvulus. Spinal supplemented by G.-O.-E.	8/9/37 1:45 P.M.	213	430	16.5	45.7%	1.0266	6.7%	appendix and some free fluid. Pain, vomiting and distention persisted. R.B.C. 6,000,000; Hb. 98%; sp. gr. of blood 1.0577. *Potassium content of gastric suction 46.9 mg.%*	
			6 P.M.	170	318	15.5	48.7%	1.0248	6.1%	This sample after infusion, operation and transfusion. *Potassium content of intestinal fluid 32.7 mg.%* *Potassium content of peritoneal fluid 17.4 mg.%*	
			8/11/37 8 A.M.	143	316	13.1	40.9%	1.0239	5.8%	Kept in oxygen tent for 2 days. Gastric suction maintained for 5 days. *Potassium content of gastric suction 49.7 mg.%*	
			8/12/37 10 A.M.	159	361	13.1	40.4%	....	....	CO_2 51 vol. %. Ser. chlorides 602 mg.% *Potassium content of enterostomy drainage 26.9 mg.%* *Potassium content of gastric suction 18.5 mg.%*	
			8/17/37 8 A.M.	160	374	12.4	39.5%	1.0238	5.8%	Bl. Urea N. 6 mg. %. *B. coli* infection of wound	
			9/1/37 8 A.M.	170.3	364	14.2	43 %	1.0269	6.8%	Enterostomy tube removed 14 day. Discharged today. Average fluid intake for first week: 4,600 cc. a day. Average daily sodium chloride 35 Gm.	
										Location of lesion: Twist at upper and lower ileum	Cured 9/1/37

obstruction, hemorrhage into the loop, and tissue necrosis together with inadequate excretion.[107] Analysis of gangrenous loop fluid in four (Cases 5, 14, 20, and 22) revealed potassium content many times that of plasma, whereas, normally, the potassium content of succus entericus is the same as that of the plasma.[20, 128]

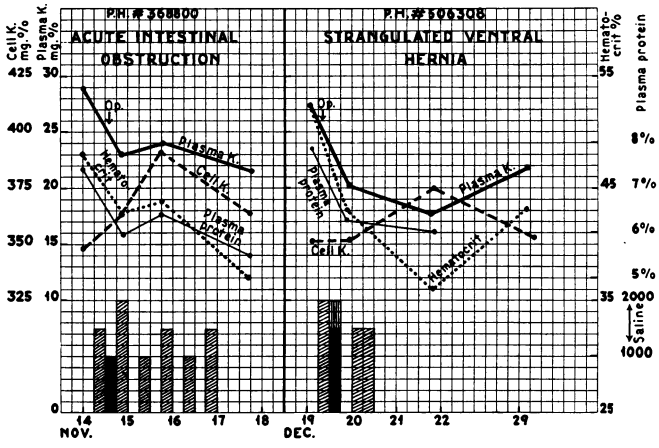

CHART 7.—Ordinates: Days. Abscissas: Plasma and cell potassium plasma protein and hematocrit readings. At bottom of chart the amount of fluid administered parentally is indicated. Solid black represents intravenous Ringer's solution; slanting lines Ringer's solution by clysis. See Cases 3 and 4 for details. Note the fall in plasma potassium and the rise in cell potassium after the administration of saline solution. Blood dilution is indicated by the fall in the hematocrit readings and plasma protein. Recovery in both cases.

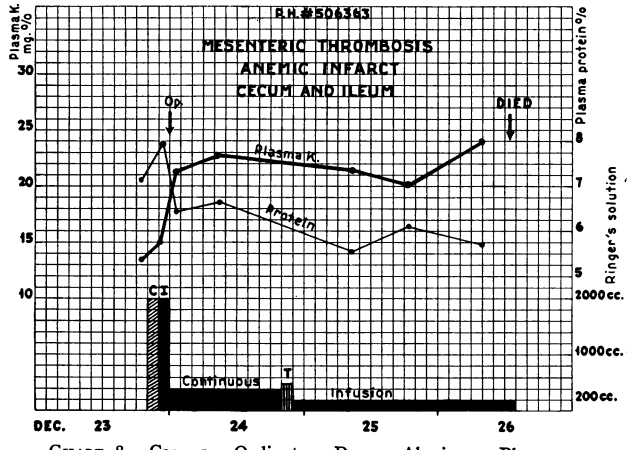

CHART 8.—Case 5. Ordinates: Days. Abscissas: Plasma potassium and plasma protein. In spite of the administration of saline solution the plasma potassium continued to rise. Autopsy showed extension of the gangrenous process.

A resection of the gangrenous loop with a primary anastomosis gave the best results in the moderately toxic patient[58] (Chart 6), probably for the following reasons: (1) The exclusion of the danger of perforation; (2) the elimination of infection; (3) the removal of the necrotic portion of the intestine with its abnormally high potassium content; (4) the maintenance of the

continuity of the gastro-intestinal tract with its base and fluid conserving function.

Enterostomy.—In this series, a primary enterostomy with the relief of obstruction measurably increased the mortality rate (Chart 5). Its surgical

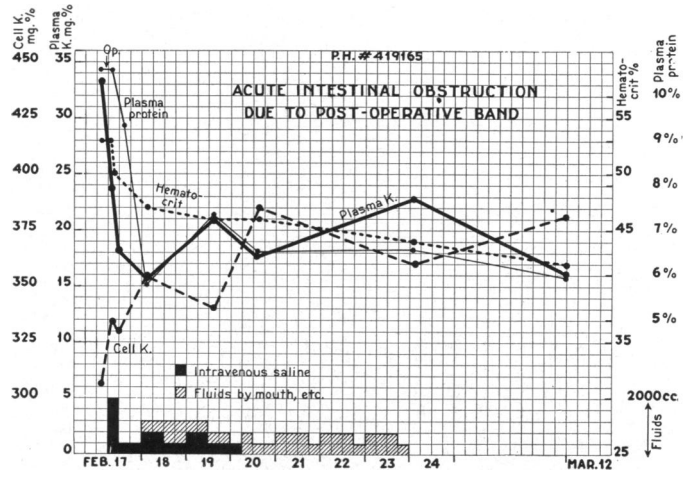

CHART 9.—Case 9. Ordinates: Days. Abscissas: Plasma and cell potassium, plasma protein and hematocrit readings. With the administration of saline solution the blood dilution is indicated by the fall in plasma protein and hematocrit readings. Plasma potassium fell and the cell potassium rose.

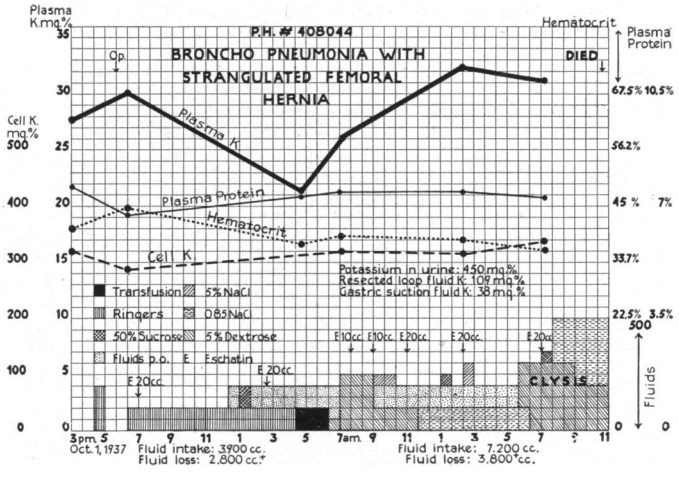

CHART 10.—Case 20. Ordinates: Time in hours. Abscissas: Plasma and cell potassium, plasma protein and hematocrit readings. At bottom of chart the types and amounts of fluids administered are detailed. In estimation of the fluid loss, 1,500 cc. were allotted to insensible perspiration. See case report for details.

merits have been controversial.[28, 65, 82, 111, 122, 124] Haden and Orr,[41] Dragstedt,[25] and Morton and Pearse[86] have shown that animals with intestinal fistulae died with the same manifestations of toxemia, and as soon as animals with obstruction at the same level. We have investigated the effect of complete intestinal fistulae upon both hemoconcentration and blood potassium and

find the resultant hyperpotassemia similar to that occurring in acute intestinal obstruction,[107, 108] experimental adrenal insufficiency,[123, 137] and experimental potassium poisoning.[139]

The 70 per cent mortality following enterostomy *without* the removal of the lesion (Chart 5) may thus be explained by two factors: (1) In failing to remove the obstruction, absorption of fluids and intestinal secretions is prevented; (2) the external loss of fluids and electrolytes through a fistula placed above the obstruction accentuates the dehydration with consequent earlier and greater rise in blood potassium.[108]

Enterotomy.—This was performed in 63 cases with a gross mortality of 57 per cent. Comparing this group with the relief of obstruction and enterostomy, the mortality in the latter is 9 per cent higher and the recovery rate is less at each index (Chart 5). This contrasts with Holden's[52] success, ob-

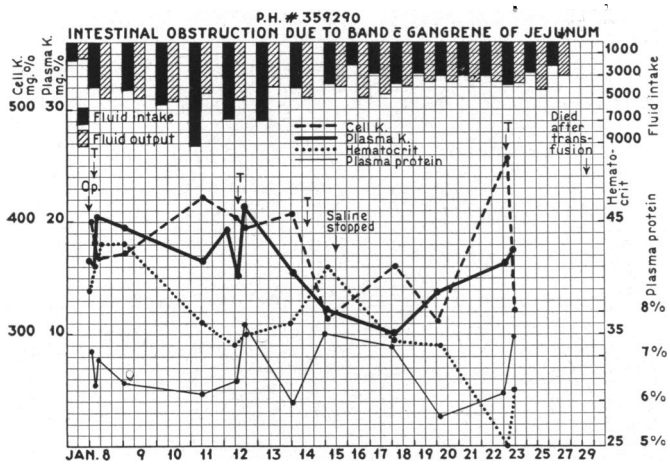

CHART 11.—Case 22. Ordinates: Days. Abscissas: Plasma and cell potassium, plasma protein and hematocrit readings. Daily fluid balance is indicated at top of chart. T indicates transfusion. Note the fall in cell potassium following each transfusion, also the increase in plasma proteins.

tained by relieving the obstruction, removing the intestinal content by stripping through an enterotomy, and the giving of hypertonic salt solution subcutaneously. His procedure eliminates the toxic intestinal fluid (rich in potassium); preserves the continuity of the gastro-intestinal tract and combats a potential hyperpotassemia by the *adequte administration of salts and fluids.* In our series, the gut was stripped in only two cases. More chemical studies on both the blood and intestinal contents are needed in this controversy of enterotomy *versus* enterostomy.[16, 62, 85, 87, 90, 115] Continued gastric suction has reduced the need for either.[78, 95, 126]

Gastric Lavage.—Introduced by Kussmaul[59] in the treatment of intestinal obstruction, gastric lavage is a recognized procedure. The advent of continued gastric suction has carried the value of decompression one step farther. Carlson[13] suggested some noxious element was washed out by vomiting. In our experimental work, the abnormally high potassium content of the vomitus indicates that secretion of this base into the gastric lumen, followed by vomit-

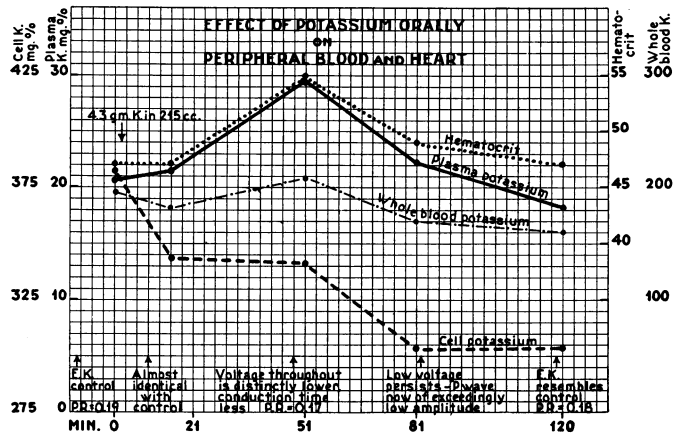

CHART 12.—Ordinates: Time in minutes. Abscissas: Hematocrit readings: Whole blood, plasma and cell potassium. A summary of the electrocardiographic data is to be found at the bottom of the chart.

CHART 13.—Electrocardiographic Report: Leads 1, 2 and 3. Taken September 8, 1936. Control: Sinus rhythm. Ventricular rate 80 P–R = 0.17 to 0.19. Left preponderance. P_3 inverted. T1, T2, T3 upright. Well-marked left preponderance is the chief finding.

ing, may be regarded as part of an auxiliary or emergency mechanism for lowering blood potassium.[34, 54, 107, 108] The values are reported in eight cases.

Pulse in Obstruction.—The slow pulse is often deceptive. Eisberg[29] counsels against delaying operation until disturbances in the pulse become manifest.

The action of potassium on the heart both *in vivo* and *in vitro* has been amply demonstrated.[12, 22, 37, 53, 73, 79] Gautrelet[35] introduced into frogs' circul-

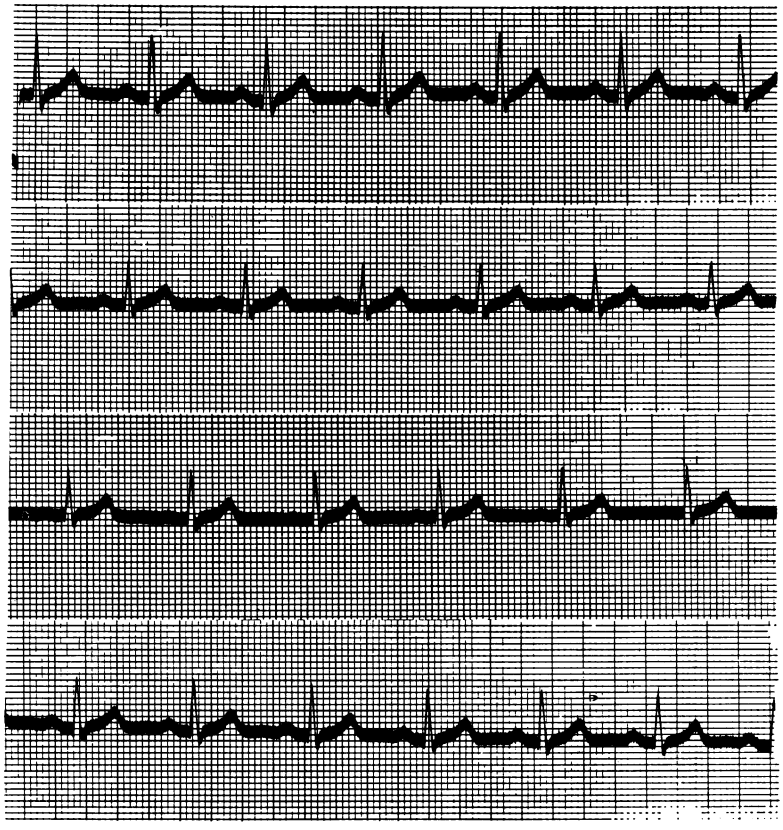

CHART 14.—Electrocardiographic Report: Series of lead 2 after taking potassium.
Sec. 1—sinus rhythm, ventricular rate 80 P–R = 0.19
Sec. 2—sinus rhythm, ventricular rate 78 P–R = 0.17
Sec. 3—sinus rhythm, ventricular rate 76 P–R = 0.15
Sec. 4—sinus rhythm, ventricular rate 80 P–R = 0.18
Section 1 is essentially identical with the control. There is not, however, the variation in the P–R as noted in the control. The form of the complexes is similar.
Section 2. The voltage throughout is distinctly lower and the conduction time is less than before, being 0.17 throughout.
Section 3. The low voltage persists, the P-waves now being of exceedingly low amplitude and the conduction time is further reduced to 0.15.
Section 4. This resembles very closely the first section in that the voltage is higher than in the second and third sections. The conduction time is greater.

lation potassium ions obtained by electrolytic dissociation, and found that like potassium salts, they produce a decrease in the number of contractions, a gradual diminution in the amplitude of the beat, and finally cessation of the heart action, electrocardiograms taken resembled those of muscular fatigue.

A relationship of hyperpotassemia to some of the peculiarities of heart action is suggested by two sets of experimental data and two human cases. As part of a study of human potassium tolerance[138] one of us (J. S.) took 20 mg. of potassium per pound of body weight. Electrocardiograms taken at intervals revealed that with an increase of 50 per cent in the capillary plasma potassium, there occurred a slowing of the rate, a decrease in the p.r. interval and a decrease in the amplitude of the complexes; all of which disappeared within two hours, at which time the plasma potassium had returned to normal.

A cat with a complete intestinal fistula showed, in addition to the above changes, T wave changes in leads two and three.[108] Cats dying of potassium poisoning gave the following electrocardiographic changes: Flattening and inversion of T waves in leads two and three; and intraventricular block and ventricular fibrillation.[15]

Case Report.—Case 2: A male, age 60, was admitted September 24, 1936, with the complaint of severe epigastric pain of eight hours' duration. The past history was important as he had had a partial thyroidectomy for cardiac insufficiency due to hyperthyroidism in May, 1935. The patient was referred to the Medical Service with a tentative diagnosis of coronary thrombosis because his electrocardiogram was suggestive of severe heart muscle damage. The exacerbations of the patient's pain, blood pressure, which remained constant, and good heart sounds were not consistent with coronary occlusion. Difference of opinion delayed operation for two days. An obstruction due to a band was found. The electrocardiograms showed improvement after treatment. The plasma potassium was 29 mg. per cent before, and 17 mg. per cent after operation and therapy.

Dr. Levy recalled another patient whose unusual history, absence of typical physical findings and electrocardiograms suggestive of severe heart muscle damage was watched for six days. Necropsy revealed several feet of gangrenous intestine, but no heart disease.

THE ACTION OF SALT.—In four conditions associated with dehydration, salt solutions have proved beneficial: *i.e.,* Asiatic cholera, fistulae of the gastro-intestinal tract, adrenal insufficiency and acute intestinal obstruction.

(1) *Cholera.*—Although intravenous saline was first used by Latta,[60] during the 1831–1832 Edinburgh epidemic,[61] the mortality for this disease was not appreciably decreased until Rogers[99, 100] introduced his treatment. The rediscovery of a low plasma bicarbonate by Sellards[109, 110] led to sodium bicarbonate therapy, which resulted in fewer cases of terminal uremia.

(2) *Salt Treatment in Intestinal Fistulae.*—Pawlow,[96] prolonged the lives of dogs with pancreatic fistulae by feeding sodium bicarbonate. The administration of sodium chloride and sodium bicarbonate has yielded similar results in other types of fistulae of the gastro-intestinal tract.[14, 26, 30, 32, 46, 86, 125]

(3) *Salt Treatment in Adrenal Insufficiency.*—Soddu's[112] observation, in 1898, that adrenalectomized animals given salt lived longer, was neglected until recent confirmation.[1, 5, 18, 43, 70, 102, 113, 134] Lowered alkaline reserve and the benefits of sodium bicarbonate and other sodium salts have been emphasized in this condition. In the adrenalectomized animals, the giving of sodium bicarbonate in amounts proportional to the lowered CO_2 was suggested by Zwemer.[140]

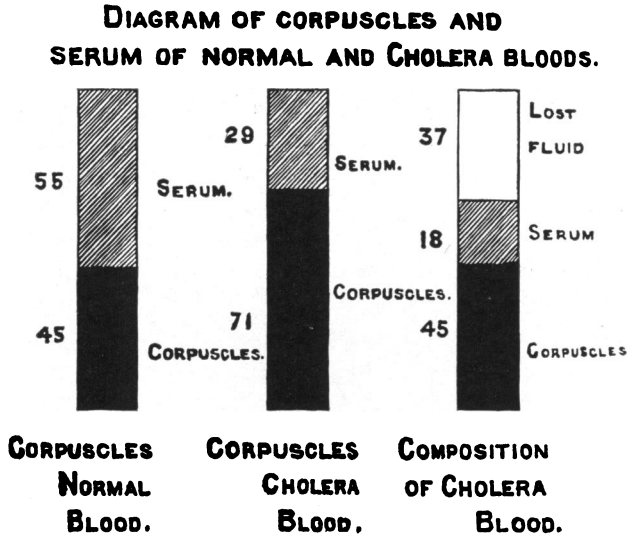

FIG. 1.—Hematocrit readings (cell volume) of normal and abnormal blood (Rogers[100]).

TABLE III

MORTALITY IN CHOLERA

Date	Type of Saline	Cases	Deaths	Mortality Per Cent
1831 (Latta and Mackintosh[61])	Saline intravenous	166		84
1893 (Wall[61])	Hypotonic subcutaneously	193		70
	Calcutta Medical College Hospital Series			
1895–1905	Rectal and subcutaneous hypotonic saline	1,243	783	59
1906	Normal saline intravenous	112	57	51
1907	Rectal and subcutaneous saline	158	94	59.5
1908–1909	Roger's hypertonic saline intravenous	294	96	32.6
1910–1914	Roger's hypertonic saline intravenous and permanganate per os	858	222	26
1915–1919	Roger's hypertonic and Roger's alkaline saline intravenous and permanganate per os	1,429	298	20.8

Formula for Roger's saline solution:

Sodium chloride..... Gr. 120 (8.0 Gm.)
Potassium chloride..... Gr. 6 (0.4 Gm.)
Calcium chloride..... Gr. 4 (0.25 Gm.)
Distilled water..... one pint (568 cc.)
This prescription, therefore, contains 15.2 Gm. per liter, constituting a 1.52 per cent solution.

(4) *Salt Treatment in Intestinal Obstruction.*—Hartwell and Hoguet[48] showed the survival period in the obstructed dog was doubled by subcutaneous salt solution injections. Similar to Rogers'[99, 100] treatment of cholera, Haden and Orr[40] have advocated hypertonic saline in bowel occlusion. In the extremely toxic patient, Orr has urged a 2 per cent salt solution by hypodermoclysis, and a 3 to 5 per cent solution intravenously, the initial dose being 1 Gm. of NaCl per Kg. of body weight, in order to restore the blood chlorides.

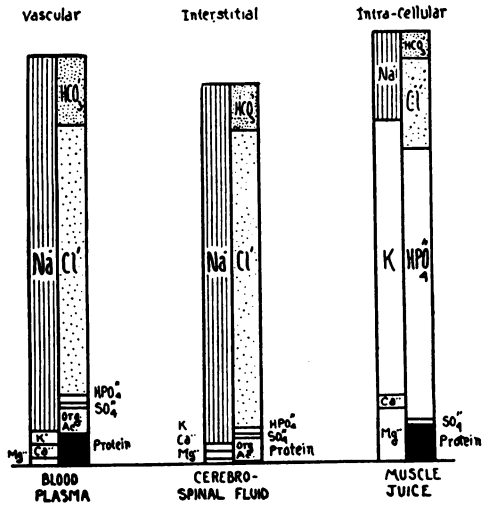

FIG. 2.—Acid-base composition of body fluids. This diagram is constructed from average values for individual factors expressed in terms of acid-base equivalence: *i.e.*, as cubic centimeters of tenth normal solutions per 100 cc. of fluid. Base factors are superimposed in left hand and acid factors in right hand of each column. They represent, as is actually the case, a structure composed not of salt but of individually sustained concentrations of ions. Exact acid-base equivalence indicated by equal height of two parts of each column is obtained by adjustability of bicarbonate ion concentration (HCO_3) to any change elsewhere in structure. (From McIver, M. A.: Acute Intestinal Obstruction, New York, Paul B. Hoeber, Inc., 1934.)

Hypertonic salt solutions shorten the survival in experimental adrenal insufficiency.[76] It appears from our experience that these strong solutions should *not be used alone in severe dehydration* because the resultant blood dilution is accomplished by ingress of cell water.

The similarity of the blood changes in the above four conditions is striking, and the values reported in the literature for three of them are given. In each, the beneficial action of sodium solutions has been attributed to correction of the altered biochemical changes of the blood, maintenance of blood volume, or the washing out of a hypothetical toxin.[100, 102, 105]

Since an increased blood potassium is found in certain phases of Asiatic cholera,[3, 104] adrenal insufficiency, intestinal fistulae, and acute intestinal obstruction, the success of saline therapy[2, 11, 51, 68, 120] might be attributed in part to its effect on potassium metabolism.

TABLE IV

SIMILARITY OF CERTAIN CONSTITUENTS OF THE BLOOD IN CHOLERA, ADRENAL INSUFFICIENCY AND ACUTE INTESTINAL OBSTRUCTION

Physical Characteristics	Asiatic Cholera	Adrenal Insufficiency	Acute Intestinal Obstruction
Red blood cells	Increased [71, 100]	Increased [36, 101, 114]	Increased [38, 81, 121]
Hemoglobin	Increased [71, 100]	Increased [44, 101]	Increased [4, 10, 64]
White blood cells	Increased [71, 100]	Increased with terminal fall [135]	Increased [121]
Specific gravity of blood	Increased [92, 100, 129]	Increased [101, 114]	Increased [107]
Hematocrit	Increased [92, 100]	Increased [7, 44, 114]	Increased [4, 38, 81]
Total solids	Increased [3, 104, 129]	Increased [23, 36, 47, 101]	Increased [55]
Anions			
Cl	Decreased [3, 93, 94, 99, 104]	Decreased [5, 7, 70, 101, 137]	Decreased [10, 31, 34, 39, 50, 72]
HCO_3	Decreased [67, 94, 110]	Decreased [70, 116, 118, 132]	Increased [31, 34, 39, 72, 80] Decreased [81]
HPO_4	Increased [66, 71]	Increased [47, 69, 116]	Increased [4]
SO_4	.....	Increased [69]	Increased [4]
Proteins	Increased [66]	Increased [49, 114, 117]	Increased [4, 31, 38, 81]
Total acid	Decreased [66]	Decreased [118]	Decreased [4, 31, 34]
Cations			
Sodium	Decreased [3, 104]	Decreased [7, 70, 76, 137]	Decreased [4, 31, 34, 50]
Potassium	Increased [3, 104]	Increased [1, 7, 42, 49, 69, 75, 137]	Increased [19, 107]
Calcium	Increased [71]	Increased [7, 47]	Increased [50]
Magnesium	Increased [104]	Increased [7, 137]	Increased [83]
Total base	Decreased [66]	Decreased [7, 45, 69, 137]	Decreased [4, 31, 34]
Nonprotein Nitrogen	Increased [21]	Increased [5, 77, 101]	Increased [17, 24, 38, 119]
Urea	Increased [93, 94]	Increased [5, 97, 101, 103]	Increased [24, 38, 83, 119]
Uric acid	Increased [71]	Increased [47, 103]	Increased [10, 34]
Creatinine	Increased [71]	Increased [42, 47]	Increased [10, 34]
Blood Sugar	Increased [71]	Decreased [8, 114, 131, 136]	Increased [13, 24]
Hydrogen Ion Concentration	Increased [66, 67]	Increased [49, 116, 132]	Increased [50]

SUMMARY

(1) Two thousand, one hundred fifty cases of acute intestinal obstruction, objectively analyzed, are reported with an evaluation of various surgical procedures used in relation to the patient's condition.

(2) Twenty-five additional cases are given in detail with determinations of plasma and blood density; hematocrit; plasma proteins; plasma, whole blood and cell potassium together with other constituents of the blood before and after therapy.

(3) The potassium contents of gangrenous loops, enterostomy drainage, gastric secretion, peritoneal and spinal fluids are given of several.

(4) Disturbances in blood potassium resulting from derangements in body fluids explain some of the symptoms found and the procedures used in acute intestinal obstruction.

(5) Hyperpotassemia is not peculiar to intestinal obstruction, but may be expected in all conditions associated with rapid, or excessive, entry of potassium into the blood stream together with dysfunction of the numerous regulatory mechanisms.

We wish to express appreciation to the following hospitals and personnel for the use of their records:

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