ACIDOSIS IN OPERATIVE SURGERY

A STUDY OF ITS OCCURRENCE DURING OPERATION AND ITS TREATMENT BY GLUCOSE AND GUM ACACIA GIVEN INTRAVENOUSLY

By Lilian K. P. Farrar, M.D.
New York

(By Invitation)

It has long been known to physiologists that there is an alteration of the chemical composition of the blood during states of activity, emotion, starvation, etc. The importance of this alteration has been recognized for several decades in internal medicine, but it has not until recently seemed to play any role in surgery for the reason that here the interest has centered chiefly upon examination of the tissues removed. Pathology is in its rightful place, but physiology has lagged behind. It is of the greatest scientific value that all pathologic specimens should be carefully examined and studied, but it is equally important that the living patient should be as carefully examined and studied before and during the operation as the dead specimen afterward. It is here that the surgeon must call upon the biologic laboratory, for it is not sufficient to have a knowledge of physics and chemistry, but one must have a knowledge of physical and chemical action in the living organism, and it is necessary that one should have a biologic conception of the general metabolism of the body in health to find the cause and remedy when disorganized.

The physiologist and the internest at times approach to one another, but rarely do the surgeon and physiologist come in contact, and yet how much greater the need as the time may be all too short for the study of a condition suddenly confronting the surgeon at or immediately following an operation. During the war the government of this country and of others, notably of Great Britain, called upon the physiologists to investigate and find, if possible, remedies for certain surgical problems. A committee was appointed by Great Britain as a "special investigation committee on surgical shock and allied conditions." With such a step forward to making the laboratory and the operating room more intimately associated it would seem that biologic chemistry had come into its proper field if the methods of examination could be shown to be simple, adequate and of practical value.

The development of the theory of acidosis has been a gradual one and chiefly applied to diabetes or nephritis; but its importance in estimating a surgical risk, or its possible value during operation as an indicator of pending shock, is only of recent growth, and it is with the object of ascertaining its value under such conditions, that the present study has been made.

The word acidosis was first used by Naunyn to designate a condition in which certain acetone bodies were excreted in the urine of diabetic patients, but the term has gradually acquired a broader significance until, as defined by Sellard, the essential feature of acidosis is a general impoverishment of the body in bases or in substitutes which generally give rise to bases, so that the body, as a whole, shows some systemic abnormality.

The chemical composition of the blood in health is maintained at nearly constant level by the general metabolism of the body:

A. Energy is produced by—
   1. Carbohydrates, which are base-forming foods.
   2. Fats, which are base-forming foods, but which need carbohydrates for their complete oxidation, otherwise they break down into oxybutyric or beta oxybutyric acid.
   3. Proteids, which are the acid-forming foods of the body.

B. Elimination is accomplished by—
  1. Kidney tubules, excreting mineral acids, urea and nitrogen.
  2. Lungs, giving off carbon dioxide and water vapor.
  3. Sweat glands.
  4. Intestinal tract.

If metabolism is faulty then there may be an accumulation of acid by-products in the body, due either to excessive production or to defective elimination, or both together, and a condition of acidosis results.

If we stop for a moment to consider the regulation of respiration in health the importance of this condition will become evident.

The work in 1905 of Haldane and Priestley on "The Regulation of Lung Ventilation" marked an epoch in our knowledge of the factors controlling respiration and has led to the so-called "New Physiology" and aroused interest in the study of the chemical constituents of the blood. These investigators found that lung ventilation is due to the response of the respiratory center to changes in carbon dioxide tension of alveolar air and arterial blood and not to stimulation of the vagi nerves. For each individual at rest, and under normal atmospheric conditions, the normal alveolar CO_2 pressure appears to be an extraordinarily sharply defined physiologic constant, but a slight rise or fall in the alveolar CO_2 pressure causes a great increase or diminution in the lung ventilation. As CO_2 in watery solution (and the gas CO_2 combines in the tissues with H_2O) becomes like a weak acid by virtue of the H-ion, and dissociates into

$$CO_2 + H_2O \rightleftarrows H_2CO_3 \rightleftarrows H + HCO_3$$
$$\downarrow \quad \uparrow$$
$$H+ \quad CO_3$$

it has been thought that the H-ion of the blood which is practically constant (while the CO_2 fluctuates) is the respiratory factor, but later investigators believe that the CO_2 in the blood has an influence not due to H-ions but due possibly to a specific effect of the undissociated CO_2, either directly stimulating the respiratory center itself or in increasing its irritability to the H-ions.

The hemoglobin of the blood carries oxygen from the lungs to the tissue cells of the body, and it is from within these tissue cells that carbon dioxide is produced. The exchange of these two gases constitutes the internal cellular respiration.

The tension of arterial blood leaving the lungs is 40 mm. and in the alveoli of the lungs is 80 mm. It is because of the low tension in the arterial blood and the higher partial pressure of carbon dioxide in and around the capillaries that gas is taken up by the bicarbonates in the blood to be given off in the alveoli of the lungs. The bicarbonates of the blood, the so-called "buffer substances" of the blood, are then the carriers of the acid by-products of metabolism to the alveoli of the lungs and constitute the alkali reserve of the body. If the bicarbonates are present in the blood in large amount the combining power of the blood, that is the ability of the bicarbonates to unite with CO_2 is high, hence the CO_2 tension in the blood is low; but if there is a diminution of the bicarbonates the carbon dioxide will accumulate in the tissues and the increased CO_2 tension in the blood will stimulate the respiratory center to increase respiration. If alveolar ventilation is not then obtained a condition of intracellular acidosis results, with serious disturbance to internal respiration.

We may liken lung ventilation to an omnibus line with limited seating capacity. If the buses are full the crowds in the streets stimulate the starters to telephone the central office to increase the number and speed of the buses. If all available omnibuses are in circulation and the crowds still increasing the people must find other ways to return home or the congestion will block the road and overflow into the side streets.

Blood bicarbonate is then the criterion of the acid base balance of the body and its percentage in the blood is a most important factor in surgery. During operation, owing to the increase in acid metabolism and also to the fact that anesthesia affects the liver, which is the regulator of acid by-products, there is a considerable drop in the alkali reserve, but as long as there are fixed bases in the blood the elimination of carbon dioxide will continue. If the alkali reserve is high to begin with the drop may not be great enough to cause a severe acidosis. But the "more marked the existent acidosis to begin with the more sensitive is the patient to operative procedures, and the more likely is he to be let down by them into a region of danger."

Lusk proved experimentally that an individual can go without food for a number of days without producing an acidosis, as Nature has time to regulate metabolism by drawing upon the stored bases in the body. But in hemorrhage and shock, where there is a lowered blood volume with either actual loss of blood from the body or with stagnation of blood in the capillaries, the fall in alkali reserve in a very short period of time may be so great that the tissues cannot adjust themselves to the altered metabolism and fail to maintain respiration.

The question naturally arises as to where the loss in bicarbonates occurs, and several ways are possible.

1. By excessive pulmonary ventilation.
2. By acetone bodies in the urine.
3. By organic acids other than acetone bodies.
4. In the tissue cells of the body.

Henderson and Haggard believe that the loss occurs in excessive pulmonary ventilation during anesthesia, and that it is preventable by breathing 7 per cent. carbon dioxide air. Reimann and Bloom, however, have shown that blood-acetone bodies account for 20 to 100 per cent. of the lost bicarbonates (on an average 60 per cent.) and possibly organic acids other than acetone bodies account for an additional amount. Caldwell and Cleveland, of the Presbyterian Hospital, found acetone present in 72 per cent. of cases following operation and diacetic acid in 56 per cent. Morris, in Deaver's clinic, reported 61 per cent. acetonuria in postoperative cases.

It would seem reasonable to conclude that in mild cases without shock or hemorrhage the fall occurs in the first three ways, and in hemorrhage the actual loss of blood from the body would account for an additional loss of bicarbonates; but in shock we must look for another cause, for it is here that there is the greatest fall in the alkali reserve.

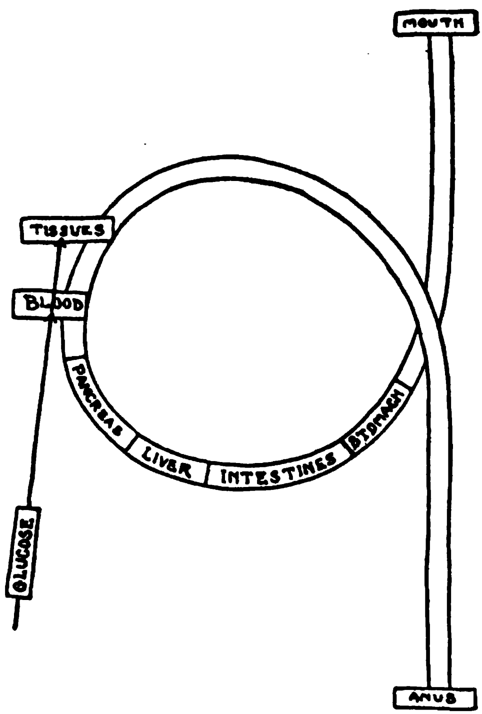
Cannon showed by his work on soldiers suffering from shock that when blood-pressures were equally reduced, hemorrhage alone was not attended by as great a reduction in alkali reserve as in shock, and, further, that the urine in shock did not show diacetic acid.

The acidosis of shock cases then must, according to this evidence, be due to some other alteration of the blood other than the production of acetone bodies. With the development of shock there is an actual loss to the circulation of a large volume of blood which recent investigation has proved lies not in the large veins of the body but is stagnant in the capillaries, and it is here and in the tissue cells that the carbonates of the blood remain and consequently are out of currency and for this reason are lost to respiration of the tissues.

The increase of sugar in the blood during hemorrhage and shock has been the subject of investigation for a number of years. Shenck found experimentally when hemorrhage was produced after ligation of the liver vessels that there was then an actual decrease in blood sugar, thus pointing to the liver as the source of the increased supply. Tatum states there appears to be a reciprocal relationship between the rise in blood sugar and the fall in alkali reserve in these conditions. This would seem to imply an effort on the part of Nature to supply sugar as the agent to offset the destructive effect of a loss in blood to the tissues of the body.

It is because of this fact that glucose was chosen for the following experiments and also because of its food value:

A large percentage of the glucose normally present in the plasma of the blood (0.08 per cent.) is not combined but circulates free in the blood, and is assimilated in this form without further change. Glucose has a nutritive value of four calories per gram, is non-toxic, diuretic and is readily obtained and easily prepared and kept in stock solution. It is not stored in the tissues, as is salt when given in hypertonic solution; nor is there a danger to other tissues, as in giving large doses of bicarbonate intravenously. Doyon and Duport, in 1901, and Blumenthal, in 1906, discovered that the rate of utilization of sugar by the tissues depended upon the velocity of injection. Woodyatt and his co-workers have proved by actual experimentation that an individual will absorb each hour 0.8 of a gram of glucose for each kilogram of body weight



Glucose is absorbed directly from the blood by the tissues without further metabolism, thus saving the gastro-intestinal tract.

without glycosuria and that the rate can be maintained for hours if desired. Thus a woman weighing 65 kilograms (approximately 150 pounds) would receive 52 grams or 208 calories per hour given intravenously. If given by mouth, subcutaneously, or put into the bowel, Woodyatt says glucose does not pass into the blood faster than an approximate rate of

1.8 grams an hour at most, which is not sufficient to permit much glucose to escape utilization. The nearest possible approach to a scientifically accurate method of sugar-tolerance measurement must be by direct vascular administration. Each tissue then receives its share in proportion to its vascularity and absorption plays no part, as the liver is not necessary for the utilization of sugar in the blood. If the resting requirement of the patient (of 125 to 150 pounds) is 1800 to 2000 calories per day she will receive in twenty-four hours 4992 calories, or more than double the actual need at rest and sufficient for the loss incurred during heaviest work. In an operation of two to three hours' duration she would receive 400 to 600 calories, or one-fifth to one-third of the total need for metabolism in twenty-four hours. Glucose is not only a food and source of energy but is a stimulant to tissue cells of the body, raising the whole metabolism and thus saving the liver function and restoring glycogen reserves. It increases not only the power of involuntary muscle fiber but has, according to Lusk, a specific effect on the heart muscle itself.

If glucose is to be injected for several hours and the rate of tolerance has been exceeded, or if for any reason it is desired to ascertain the sugar tolerance an examination of the urine one-half hour after the injection has been made will show sugar present in the urine if it is going to be at all. The effect of sugar if the rate has been exceeded is a marked diuresis, and plenty of water should be given to counterbalance this loss of body fluid. If the rate of absorption is adhered to both the danger of dehydration of the tissues on the one hand and of overburdening the heart with too large a volume of fluid will then be avoided.

The solution of glucose was made from C. P. anhydrous dextrose and distilled water. A 20 per cent. solution was used as sufficiently hypertonic to avoid hemolysis, and flasks of 250 c.c. were sterilized in the autoclave and kept in an ice-box near the operating room for emergency cure. Injection is made in the vein of the forearm during the operation and the rate of flow regulated by a stopcock on the tube. The rate is easily calculated as follows: If the subject weighs 65 kilograms the rate is 0.8 of a gram per kilogram and the solution 20 per cent. Multiply 0.8 $\times$65 $\times$ 5 (*i.e.,* 20 per cent.) equals 260 c.c. per hour; divide 260 c.c. by 60 (minutes) equals 4.3 c.c. per minute, or approximately one flask an hour, to the average patient, more, of course, if the weight is greater.

Woodyatt has devised a volumetric electric pump by means of which the rate and amount can be accurately gauged, but while its desirability is great for hospital work the cost is considerable and any method for arsphenamin injection is satisfactory. The solution should be given at 105° F., and if it is poured into the container at 115°F. and the tubing placed between two hot-water bags the heat will be maintained throughout the administration. An infusion thermometer in the lower end of the tubing ensures an accurate temperature.

While glucose has been used in this series of cases to combat the acidosis incident to operation it has been given in cases of peritonitis and in exhaustive postoperative vomiting to maintain nutrition, and with most beneficial results. There is in such cases a great loss of fluid from the body in addition to what the patient lost during operation, and metabolism fails because Nature cannot utilize the stored protein and fat in the body without water. In such cases an isotonic (5 per cent.) or hypotonic (2 per cent.) solution may be preferable for a time to restore body fluids; but the blood-pressure should be watched that the heart be not overburdened with a large volume of water suddenly injected into the veins, and, generally speaking, the hypertonic solution (15 to 25 per cent.) is preferable intravenously and the Murphy drip 5 per cent. glucose given by rectum or saline subcutaneously until the patient is able to take fluids by mouth. It is in the cases of extreme vomiting, of acidosis, either postoperative or in pregnancy, in peritonitis and in postoperative uremia, where, as Crile says, blood transfusion has no value, that glucose intravenously furnishes the means to combat the condition. It has (as Litchfield found who has used glucose intravenously in pneumonia with excellent results) a beneficial action that seems to last beyond the time of injection, due, according to Woodyatt, to the reëstablishment of the oxygen supply caused by improvement of the blood-flow through the part and the resultant diminution of asphyxial acid accumulation.

So far glucose has been spoken of only in relation to a fall in the alkali reserve occurring in an operation without any appreciable degree of shock. We approach now a condition where the most marked changes may occur in a short period of time producing, with or without excessive energy transformation, a condition of intracellular acidosis and consequent disturbance or cessation of the interchange of gases within the cells themselves and resulting in interference with intracellular respiration, which is life itself. The histologic changes in the cells of the brain, liver and adrenals appear within a few hours and indicate the profound alteration produced by this state.

As Cannon has shown by his investigation on cases of shock in the trenches, the fall in alkali reserve in shock (unaccompanied by loss of blood from hemorrhage) goes hand in hand with the fall in blood-pressure. If blood-pressure can be maintained or the fall diminished there must be a saving of the alkali reserve, and to this end gum acacia was added to the solution of glucose in one of the series of cases at the Woman's Hospital, which I will present.

The report of Bayliss, of the special investigation committee on intravenous injection, states that with simple saline solution of any kind the blood-pressure falls to a low level by the end of an hour or so, and the process continues until death. A secondary fall about an hour after injection sometimes occurs in the case of gum solutions, but it is not so low as that with saline at the same period, and is soon recovered from.

Bayliss also states that no solution containing salts alone is of much value, as the rise in blood-pressure is not permanent. An isotonic salt solution is deleterious as the salt solution escapes into the tissues, owing to the diminution of the colloid concentration in the blood and also diminished peripheral resistance in the arterioles and attracts the water from the blood stream after it. A hypertonic salt solution has the same effect after a short initial rise in blood-pressure.

Sodium bicarbonate given intravenously, which theoretically should be beneficial, has proved clinically dangerous, as Van Slyke has shown, by the excess bicarbonate passing into the tissues. To ensure a satisfactory rise of arterial pressure without necessity of introducing a large volume the presence of a colloid with an osmotic pressure comparable to that of the blood must be used.

Gum acacia (which is. arabinose) is a gum colloid and has been used for shock cases (in 5 to 7 per cent.) in sodium potassium and calcium salt solutions, with beneficial result, in raising blood-pressure. It is a known fact that crystalloids (to which class glucose belongs), when in the blood stream, will attract water from the tissues, and experimentally it has been proved by Erlanger and Gasser that this is the effect when glucose is injected into animals and that gum acacia will then maintain the expanded blood volume. No addition of salt is required in the solution, as the rate of injection is slow enough for the escape of salts into the blood stream.

But before endeavoring to offset the fall in alkali reserve during operation it seemed advisable to find the normal variation in women of the CO_2 combining power of the blood as the percentages given by Van Slyke (52 to 78 c.c. per cent. for 100 c.c. blood plasma) were in men. For this purpose 175 patients were examined on entrance to the Woman's Hospital, and all the examinations of the blood were made by a technician from the Rockefeller Institute by Van Slyke's own method, the principle of which is as follows:

The bicarbonate content of the arterial blood plasma is the most accurate measure of the alkali reserve of the body fluids as a whole. On account of the technical difficulty of taking arterial blood for the examination the determination is made from venous blood with only a difference of a fraction of 1 per cent., as Van Slyke has shown.

After 10 c.c of blood have been drawn into a test-tube containing a few grains of potassium bicarbonate to prevent coagulation (in the usual method for making a Wassermann) and centrifuged the determination of the carbon dioxide capacity is made. The procedure is relatively simple and requires only four to five minutes to make. Briefly it is the determination of the number of cubic centimeters of carbon dioxide gas which 100 c.c. of blood plasma will take up (*i.e.*, saturating the plasma by blowing into it) at approximately the tension of normal alveolar air (5.6 per cent., which is the end of a deep expiration) and correct for barometric pressure. The result is expressed in volumes per cent. of CO_2.

Chart I

One hundred and seventy-five patients were examined upon entrance into the Woman's Hospital for the CO_2 combining power of the blood (bicarbonate reserve):

45.8 to 50.0	per cent.	6 cases	25 cases
50.0 to 55.0	"	19 "	
55.0 to 60.0	"	60 cases	150 cases
60.0 to 65.0	"	61 "	
65.0 to 69.9	"	29 "	
		175 "	

Eighty-five per cent. of the patients had a CO_2 combining power of the blood between 55 and 70 c.c. per cent.

Of the 6 cases between 45.8 to 50 per cent., 4 cases were of inoperable carcinoma of the cervix with extensive involvement; one was a patient who had had severe hemorrhage and had a hemoglobin of 23 per cent.

The 19 cases between 50 and 55 per cent. included 2 cases of pregnancy, 1 with large fibroids of the uterus and 1 with ovarian cyst; 1 case of pulmonary tuberculosis; 2 of subacute appendicitis; 3 with menorrhagia following abortion. No one of these cases would have been considered clinically to have been more than a fair risk. The other cases were on other divisions and the history not known.

The CO_2 combining power of the blood was then ascertained for 50 patients under fifty years of age with a temperature not above 99, pulse below 90 and hemoglobin 85 per cent. or above with the result as follows:

Lowest,	55.2 c.c. per cent.	52 c.c. per cent.	Van Slyke's figures for men.
Highest,	68.9 c.c. "	78 c.c. "	

Forty of the 50 patients had a combining power of 60 per cent. c.c. or above.

It would seem, therefore, that the upper limit in women is about 8 points lower than in men (52 to 78), which corresponds to what Van Slyke has estimated, but that the lower limit in women is not so low as in men. As 50 is the figure Van Slyke has put below which an acidosis probably exists, and which seems to hold true clinically for women, this shorter range may mean that acidosis occurs more frequently in women, for we know that acetone bodies are more often found in the urine of women after operation than in men.

CHART II

Condition of subject.	Van Slyke's figures for men. Actual bicarbonate reserve.	Figures for women in the Woman's Hospital, New York.
Normal resting adult, limit of bicarbonate reserve.	Vol. per cent., 53 to 80 per cent.; range 27.	Vol. per cent. 55 to 70 per cent.; range 15.
No pronounced symptoms.	40 to 53 per cent.	50 to 55 per cent.
Moderate to severe acidosis; symptoms may be apparent.	30 to 40 per cent.	45 to 50 per cent.
Severe acidosis; symptoms of acidosis.	Below 30 per cent.	Below 45 per cent.

The shorter range in women is the reason why acetone bodies are more frequent in pre- and post-operative urine. If the upper limit of the CO_2 combining power is lower then the range is shorter and the danger line sooner reached. In 10 of Cannon's series of shock cases operated upon in the trenches the CO_2 capacity before operation was 40 per cent. or less, and in 2 of the cases the capacity fell after operation to 27 and 28 per cent. Cannon states that blood taken from the heart at the moment of death from shock has a capacity between 20 and 24 per cent. In the series of cases operated upon in the Woman's Hospital the condition was critical when the patient reached as low as 42 per cent. or 44 per cent., and blood taken from two patients shortly before death was 37 and 28 per cent. This would seem to indicate that in women not only is the CO_2 combining power of the blood plasma not as high as in men but that a critical state is reached earlier in the scale than in men.

Examination of the blood taken at the end of operation was then made in 100 cases to ascertain the fall in alkali reserve incident to the operation. The anesthetic given was nitrous oxide gas and ether by the closed method. Only one bag of gas was used, and the amount of ether varied from 2 to 17½ ounces. The time of anesthetic varied from thirty minutes to three hours fifteen minutes. The operations were gynecologic and included plastic and abdominal work and were done by ten different operators. *One hundred cases examined both before and at the end of operation showed a fall in alkali reserve varying from 0.7 per cent. to 22.2 per cent.*

Austin and Jonas reported a fall in alkali reserve during operation as follows: Lowest 4 and highest 18 volumes per cent.

Reimann and Bloom lowest 5 and highest 15 volumes per cent. Morris, from Deaver's clinic, lowest 0.4 and highest 22.7 volumes per cent.

Cannon on cases operated upon in shock lowest 6 and highest 19 volumes per cent.

Clinically when the fall reached 15 or more points the patient showed symptoms of beginning shock as evidenced by falling blood-pressure, rapid pulse and increased respiration.

CHART III

One hundred cases examined both before and at the end of operation showed a fall in alkali reserve from 0.7 to 22.2 per cent.

In 14 of the cases the alkali reserve fell 15 (or more points).

The incidence of acute acidosis during operation is 14 per cent.

To ascertain the effect of glucose feeding on vomiting, 20 patients were given glucose solution (20 per cent.) intravenously, the amount varying from 24 to 72 grams according to body weight and duration of the operations which lasted from one to three hours (anesthesia). The cases were the most critical of the series, including 2 Wertheim, 4 Mayo, 2 enteroceles, 1 resection of bowel for carcinoma of sigmoid and 3 cases of hemorrhage, 3 large fibroids and 1 large densely adherent intraligamentous cyst. The result was (Chart 4) that the vomiting was entirely absent in 16 cases and nearly so in the other 4 cases, as the amount was only one to two ounces and not more than four times in any case.

During the same period of time 10 cases were operated upon by the same two operators with an anesthesia from 58 minutes to 2 hours 15 minutes on a much less severe class of cases, and only 2 cases had a correspondingly slight amount of vomiting while the other 8 cases vomited from 24 to 59 hours.

Chart IV

The effect of glucose given intravenously upon vomiting.

20 cases given glucose (1 to 3 hours anesthesia).

In 16 cases vomiting was entirely absent.

In 4 cases vomiting was very slight (1 to 3 times).

10 cases not given glucose (1 to 2¼ hours anesthesia).

2 cases had correspondingly slight vomiting.

8 cases vomited 24 to 59 hours.

Vomiting is practically absent when glucose is given intravenously.

A comparison was then made between the fall in alkali reserve, blood-pressure, pulse-pressure, pulse-rate and respiration in 20 cases operated upon without appreciable shock. The duration of operation varied from 51 minutes to 3 hours 6 minutes. The amount of ether used was from 3 ounces to 17 ounces.

Chart V

Twenty cases operated upon without appreciable shock.

Fall in		Change in
Alkali reserve 0.7 to 11.7 per cent.	Blood-pressure 4 to 50 points.	Pulse-pressure same in 4 cases; increased 4 to 20 points in 6 cases; fall 5 to 40 points in 10 cases.

Change in	Change in
Pulse-rate same in 1 case; increased 4 to 40 beats in 14 cases; fell 8 to 26 beats in 5 cases.	Respiration rate same in 10 cases; increased 2 to 10 in 9 cases; lessened 4 in 1 case.

The fall in blood-pressure is a more reliable guide during operation to pending shock than is the alteration in pulse-rate and respiration, inasmuch as it is the cause upon which that alteration depends.

The fall in blood-pressure bears a close relation to the fall in alkali reserve. The change in pulse-rate and respiration is not constant.

The next and final step in the study was to see if blood-pressure could be maintained during hemorrhage or shock. The reports from the British special investigation committee on surgical shock of intravenous injections to replace blood and particularly upon the use of intravenous injection of gum acacia in surgical shock led to the following procedures:

Bayliss, and later Drummond and Taylor, used a 5 to 6 per cent. solution of gum acacia in salt solution of different strength. Believing that beneficial results had been obtained by glucose solution I then added 6 per cent. of gum acacia to the glucose and gave the combined solution. I found later that Erlanger and Gasser have given this same solution, but with a higher percentage of glucose (30 per cent.). Salt or bicarbonate of soda was not added to the solution for the reason, as Erlanger says, that the fluid is introduced so slowly that the water attracted to the blood stream by the crystalloid sugar brings salts with it. Absolutely no harmful result has occurred to the patients in any way. Three patients who have been given glucose intravenously for postoperative vomiting, and the rate of injection greatly exceeded, have had mild chills, but no further complication. No patient who has had a solution of glucose or gum glucose during operation where the rate was directly under observation has had a chill.

Technic of Preparation of Gum Glucose Solution

(From the Laboratory of the Woman's Hospital)

6 per cent. gum Arabic.
20 per cent. dextrose.
0.9 per cent. sodium chloride.

Procure gum Arabic, grade A, Kordofan or Egyptian, in powdered form, which will go into solution more readily than the crystalline form. If the gum is in lumps, considerable time will be saved if it is ground before attempting to dissolve it.

C. P. anhydrous dextrose is used for the solution. There are several varieties of "pure" dextrose which are much cheaper, but greater care must be exercised to remove impurities or a heavy deposit will remain after the final sterilization.

For 1 liter of gum glucose solution, weigh out 250 grams c. p. anhydrous dextrose and 60 grams gum Arabic. Suspend the gum in 300 c.c. normal salt solution, stirring until most of the gum has dissolved, and then let stand in a refrigerator overnight to completely dissolve the residue. The following day dissolve the 250 grams of dextrose in sufficient warm salt solution to make a total volume of 625 c.c. and filter through cotton. The excess quantity of solution is necessary to counteract the loss due to the filtration.

Add 500 c.c. of the dextrose solution to the gum solution and mix. Then make up to one liter with normal salt solution. Place in a boiling water-bath for a half hour, stirring frequently. This heating will dissolve the gum completely and will also precipitate out impurities in both gum and dextrose.

Again make up to 1 liter with normal salt solution. Titrate the reaction and neutralize with 10 per cent. solution sodium carbonate (approximately 15 c.c. of 10 per cent. sodium carbonate solution will be required per liter). This must be done, since the solution has been found to be quite acid (Arabic acid).

Autoclave for fifteen minutes, at 15 pounds' pressure, which will precipitate a quantity of solid matter. Care should be observed to have the solution subjected to the same degree of heat as in the final sterilization, or a clear solution cannot be obtained.

Filter through cotton and then through a Buchner filter, using two layers of linen and two of hard filter paper (Whatman, No. 50), arranged alternately and moistened on the filter with saline solution. (In layering start with linen.) The linen serves as a support for the paper, which otherwise would be sucked through the holes of the funnel under the pressure applied.

Divide into 250 and 300 c.c. lots, which are convenient amounts, and pour into clean sterilized Erlenmeyer flasks and autoclave for fifteen minutes under 15 pounds' pressure. If the solution is clear and free from sediment, it is now ready for use. If the gum glucose solution is not to be given immediately the flasks must be placed in a refrigerator, where the solution will keep for a long time ready for emergency use.

The cases were given 6 per cent. gum acacia and 20 per cent. glucose at subtolerant rate just as previously with the glucose solution. The treatment was given because of the patients showed either a low CO_2 combining power or were frankly bad risks or after hemorrhage. In two cases of 250 and 255 blood-pressure where the solution was not given until the blood-pressure had fallen 100 points, then fell only 10 and 15 points lower, and one hour after operation were above the point where they were when the solution was begun. Two cases where the solution was started late, after severe hemorrhage, and the blood-pressure had dropped 30 to 45 points, were one hour later 10 and 12 points above the blood-pressure findings at the beginning of operation. One case of three-hour anesthesia with large densely adherent cyst of the pancreas dropped 12 points. *The other 32 cases were from 2 to 30 points higher at the end of operation and only three of the above cases showed a fall in alkali reserve of 15 points.*

Chart VI

The effect of gum glucose in maintaining blood-pressure after hemorrhage or in prolonged operation in 40 cases (1 to 3 hours anesthesia).

8 cases dropped 1 to 15 points only.

32 cases were the same or from 2 to 30 points higher at the end of operation.

6 per cent. gum acacia in 20 per cent. glucose solution will help to maintain blood-pressure if given throughout an operation.

Before closing mention should be made of other tests for acidosis, the prophylaxis and postoperative treatment of this condition.

While it is believed that Van Slyke's test for the alkali reserve gives the simplest and most accurate means of ascertaining the acid base balance of the body, still an effort should be made, especially when the CO_2 combining power is low, to study the patient from all angles and fortify him against the risks of a surgical operation; and to this end the patient's metabolism and eliminative processes should be determined and an effort made to—

I. *Limit the Production of Acid By-Products.* As acid by-products result from either a deficient supply of carbohydrates or an excess of protein which gives rise to acid-forming elements and thereby depletes the stored bases of the body to neutralize the acids formed, the diet before operation should consist chiefly of starchy foods, together with vegetables and the citric fruits, which are changed to carbonates in the stomach. Shigenoba has shown by experiments that the kind of food has a marked influence upon the acid base equilibrium of the organism. Though the carbon dioxide capacity of the plasma is 61 to 64 in green diet this value is reduced to 48 to 53 on protein diet. (The hydrogen ion concentration of the blood remains constant with both kinds of diet Ph. 7.35 to 7.5.)

The postoperative diet should be of the same character, viz., fruit juices or fruit albumin, cereals (not oatmeal), citric fruits, honey, sugar, starchy foods and vegetables. As starvation is a cause of acidosis, food should be given up to a short time before operation and feeding begun early after the operation.

Bicarbonate of soda is of undoubted value in raising the alkali reserve if given for several days preceding the operation.

II. *Increase the Elimination of Acid By-Products.* 1. The Kidney: As the alkalinity of the blood is maintained for the most part by the tubules of the kidney it is of great importance to know its ability to eliminate acid by-products. In health the effete nitrogen of the proteid molecule is used to make ammonia salts and combines to form urea, but with an excess of acids the ammonia is used to neutralize them and consequently escapes conversion into urea. The relation of ammonia nitrogen to total nitrogen in health is about 2 to 7 per cent., but in acidosis it is usually over 10 per cent. and may in severe acidosis rise to 20 to 30 per cent. It is not until all the ammonia is combined that the acetone bodies appear in the urine.

(a) The importance of examining then for their presence is evident, especially in women, who Caldwell found had acetone bodies in 23 per cent. of his cases before operation.

(b) The soda bicarbonate tolerance test of Sellard is a valuable aid in estimating the amount of alkali necessary to render acid urine alkaline. In health 10 to 15 grams of bicarbonate of soda will make the urine alkaline in eight hours, but with an excess of acid in the urine the amount is greatly increased and an estimate may thus be made of the total acidity by the amount of soda bicarbonate required.

(c) The phenolphthalein test, while it shows a wide varia-

tion, points to a condition of acidosis when the total output in two hours is 30 per cent. or less.

2. The respiratory capacity of the lungs may be further studied by estimating the CO_2 tension in the alveolar air and by the simple test of Yandell Henderson for acidosis, viz., the ability to hold the breath for the normal period of forty seconds.

3. The intestinal tract and the sweat glands of the body should be considered as important factors not only in carrying off waste-products but for the loss of fluid to the body.

Purging shortly before operation and postoperative vomiting remove a large amount of water from the tissues, thus predisposing to acidosis. Patients in the calorimeter eliminate water through skin and lungs (Du Bois) at a rate which varies between ½ and 1 liter a day. In active exercise or nervous excitement the amount is greatly increased. Benedict quotes the case of a foot-ball player who lost 14 pounds in a game one hour and ten minutes long—only ¼ pound was due to the oxidation of solids—13¾ pounds was water lost.

The patient who at the end of operation has saturated the coverings above and below with perspiration greatly needs the addition of fluid which may readily be placed in the bowel (1 to 1½ quarts) while unconscious to offset this loss of fluid to the tissues, and a further addition of fluid, intravenously, subcutaneously or by Murphy drip as the need may be, is an aid to metabolism.

Summary

1. Acidosis is a term used to signify an impoverishment of the body in bases.

2. The alkali reserve (bicarbonates of the blood) is the criterion of the acid-base balance of the body.

3. The determination of the alkali reserve (*i.e.*, the number of cubic centimeters of carbon dioxide gas which 100 c.c. of blood plasma will take up) is readily made by Van Slyke's method.

4. A high CO_2 combining power of the blood is of the

greatest importance for the maintenance of lung ventilation during operation.

5. The range of the CO_2 combining power of the blood in women (150 cases) is 55.2 c.c. to 69.9 c.c. per 100 c.c. of the blood plasma, or about 8 points lower than Van Slyke found for men.

6. As the range is shorter in women the danger line is sooner reached which accounts for the greater frequency of acidosis following operations in women than in men.

7. The fall in alkali reserve during operation depends not only upon the anesthetic and the duration of the operation but upon the nature of the operation and the occurrence of hemorrhage and shock.

8. The fall in alkali reserve bears a close relation to the fall in blood-pressure and pulse-pressure. If the fall in blood-pressure is prevented there is a saving in alkali reserve.

9. A solution of glucose given intravenously during an operation at the rate of 0.8 gram of glucose for every kilogram of body weight each hour of the operation will lessen the acidosis incident to operation by promoting metabolism, prevent or diminish the vomiting and promote diuresis.

10. Glucose will appear in the urine in ½ hour if the rate has been exceeded.

11. A solution of gum acacia (6 per cent.) in glucose (20 per cent.), if given at a subtolerant rate the entire time of operation, is an aid to the maintainance of blood-pressure.

12. Carbohydrate feeding before and after the operation together with the use of bicarbonate of soda will do much to prevent or lessen acidosis.

Conclusion

Every well-equipped hospital laboratory should have a paid physiologist who could devote his time to the study of problems on the living tissue as the pathologist does on the specimens removed. The study should include the organic regulation as a whole and not individual cells or tissues. Biology would not then be divided into its branches, but would comprise a study not only of anatomy and pathology but physiology and biologic pharmocology as well. The problems should be of practical import, alike of value to patient and surgeon. The student should have made known to him the facts of general metabolism and their relation and importance to surgery. This information should not be isolated and scattered but grouped and given as a part of student work preparatory to surgical training.

As we bring a more scientific spirit to surgery we approach to what Haldane terms the humane physiology, for it is only by a study of life that we know the living and can give the sympathy and understanding which is as much a duty as is the technical skill for the true surgeon.

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DISCUSSION

Dr. Rollin T. Woodyatt, Chicago (by invitation).—I appreciate the honor of being invited to say something on this subject, and would say first, I feel Dr. Farrar's paper is one of the most rationally written papers I have heard on this subject.

There is a great tendency in using means of this sort to group certain conditions under certain clinical names, such as shock acidosis, and so on, without entirely realizing the combination of conditions which may occur in different individuals; that is, one case of shock is not necessarily like another one; hence a clear understanding of the basic principles underlying the use of these agents is important.

Gum acacia glucose and salt are all similar to each other in one respect, as Dr. Farrar has pointed out, in that they all have high hydration capacities and will hold water in combination with themselves. Whether in the bowel or kidney tubules, you will find these substances associated with water and, of course, as they pass into the blood stream they accumulate water in the blood creating the condition of hydremic plethora. Thus they increase blood volume, but these substances also differ in other respects.

An inorganic salt like sodium chlorid, when introduced into the blood, passes rapidly from the blood into the tissue cells, and being non-oxidizable, rapidly reverses the initial hydremic plethora and replaces it with hydrops of the tissues. Glucose differs from salt in the respect that after passing from the blood into the tissues it undergoes utilization (oxidation, storage) but does not accumulate as unchanged glucose in the tissues. Instead of exhibiting the hydrops-producing action of salts in the tissues, glucose substitutes for these the beneficial chemical effects which result from its utilization and, as Dr. Farrar has stated, these include the increased storage of glycogen, an increased energy in non-striped muscular fibers and increased tone, so that following glucose injections it is not uncommon to find a marked increase in the tone of the musculature of the alimentary tract from the stomach down, an effect resembling, though not quite so striking, as that of pituitrin. Gum acacia has a certain advantage over salt in that it does not diffuse into the tissues so rapidly. It therefore cannot accumulate in the tissues but remains in the blood and holds water in the place where it is wanted. It has a certain advantage over glucose, owing to the fact that after having been introduced into the blood stream all at one time the supply need not be maintained by continuous injection. It does not take the place of glucose in all respects because it exhibits none of the chemical effects of glucose in the tissues. Therefore, a combination of gum and glucose is a rational procedure.

I personally have not used gum acacia, but have been more concerned with a technic enabling us to sustain the effects of glucose as long as we wanted them by an apparatus which permits the continuance of injection for an indefinite time. Basing my remarks on the use of glucose without gum I would emphasize a point brought out by Dr. Farrar to the effect that the increase in blood-pressure, both in its height and duration, is greater than that obtainable with sodium chlorid. The improvement in the condition of the patient in shock and shock like states, particularly when there has been considerable dehydration, is more marked following glucose injections than after the use of salt solution alone, and with glucose there is no subsequent reversal of the first effect on the blood volume. So far as it goes and while it lasts the effect of the glucose is an unmitigated good. Salt has a transient effect on the blood volume and a doubtful effect on the mean arterial pressure followed often by hydrops.

In cases of resection of the bowel, in certain cases where there has been stenosis of the pylorus with marked dehydration or failure of the body to absorb the water it takes in by the alimentary route, also in cases of "transudate" into the stomach, persistent vomiting with dehydration, fever and starvation, and in several other conditions, we have obtained results with glucose which cannot be obtained by other known means.

A point which would appear to be of particular interest in relation to the gynecological operating room is the frequency, as you undoubtedly know better than I do, with which in conditions associated with pregnancy that type of acidosis occurs in which the acid accumulation is not due simply to tissue asphyxia, as in shock, but in which it is due to that derangement of metabolism which you see in fasting and in diabetes, namely, acidosis having its origin in the fatty acids and associated with aceto-acetic and beta hydroxy butyric acids in the urine. This type of acidosis is specifically combated by the administration of glucose.

So to attain the best results with intravenous injections, it is desirable to take up in each case the several items—blood-pressure, blood volume, plasma bicarbonate, the water reserve of the body, the degree of starvation, etc., and then to make an intravenous prescription for the individual case, carrying the treatment toward definite ends. Where the main lack is water, use a 3 or 4 per cent. glucose solution; for a shock-like state without dehydration, use a hypertonic solution. If there is a very low bicarbonate reserve, add enough bicarbonate to restore it to normal and make the solution and the rate of its injection fit the case.

Dr. Frederick J. Taussig, St. Louis, Missouri.—I would like to report briefly concerning 2 of my cases of postoperative shock treated by Dr. Erlanger with gum-acacia-glucose solution and included in his report on this subject. Both of them have a certain interest and lesson. The first of these cases was one of a large abdominal tumor, a fibroid, filling the entire abdomen, with an infected ovarian cyst. It was a most difficult operation in a woman whose kidneys were in bad shape, but on the advice of the internist I decided to do this rather hazardous operation. Previously I had gotten in touch with Dr. Erlanger, feeling it was a case suitable for gum-acacia-glucose injections. The blood-pressure within twenty minutes after the operation was begun fell to below 100, the pulse became rapid and imperceptible, and Dr. Erlanger proceeded to inject the solution. As you may know, he uses a stronger solution of gum acacia, 20 to 25 per cent., and a little bit higher glucose also. Within twenty-five minutes the pulse-pressure which had fallen to 3½ mm. and the blood-pressure ranging from 60 systolic to 50 diastolic as registered on the apparatus for that purpose rose to 90–65 blood-pressure, and pulse-pressure from 6 to 7 mm. The patient at the time she was removed to her room was in as fair condition as one could ordinarily expect any woman to be after a laparotomy. Unfortunately this patient died of pneumonia twenty-nine days after operation.

The second case is perhaps of greater interest because it points to the importance of the use of these solutions in cases of hemorrhage. A cervical cancer had been removed by a paravaginal operation, and on the second day after operation the patient had a severe hemorrhage. The condition was such that she rapidly became exsanguinated, and as I was unable to attend her just at this time, Dr. Erlanger was communicated with, and he felt it was a case for treatment with blood transfusion. According to the statement of the intern, a resident donor could be obtained within the period of half an hour. Unfortunately this intern was mistaken in his statement, because it was not until three hours later that a donor was found, and by that time the patient was in a dying condition.

The conclusion Dr. Erlanger draws in the cases where a blood transfusion is evidently necessary is that the gum-acacia-glucose solution if injected at once will hold the patient until such time as a donor may be available and will add to the probability of recovery.

Dr. Robert T. Frank, New York City.—My experience with gum-acacia-glucose solution was an acute one. It was in an evacuation hospital, where at one period of the conflict the patients came in with all degrees of shock, due to all possible reasons for producing shock. I include cold, exposure, hemorrhage, infection, starvation, dehydration, and so forth. We at first treated them with salt solution. (I am leaving out the other treatments of shock, only referring to those which are distinctly applicable to this discussion). An order was later issued to use gum acacia with glucose. We were asked to employ quantities varying from 700 to 1000 c.c. Without having any time or opportunity for making a scientific investigation, a large number of men who were in charge of these cases came separately to the conclusion that harm was being done by these injections. We thereupon gradually reduced the amount of injection to a maximum of 400 c.c., and our results were better.

However, we finally came to the conclusion that transfusion was far superior to any of the artificial sera which had been used. I have exchanged opinions with other men from other organizations who have arrived at the same conclusion.

Dr. Benjamin P. Watson, Toronto, Ontario, Canada.—We have been using the gum acacia solution now for nearly a year. We are fortunate in Toronto in having Dr. Keith who did a great deal of original work for the British Commission during the war, and we have come to replace normal salt solution entirely by gum acacia solution.

Our experience with saline solution in shock and hemorrhage has been that you can raise the blood-pressure at the time, and that blood-pressure would be maintained for two or three hours, then there would be a sudden fall and a beginning state of shock again, requiring a later transfusion. We know that 25 per cent. solution has been used by Dr. Erlanger, and with that percentage we find the blood-pressure can be immediately raised. We had a case of ruptured ectopic pregnancy with the blood-pressure down to 80 or 90 systolic, and then brought it up to 120 systolic during the course of the operation, and that pressure was maintained.

We have had 4 cases where we followed the blood-pressure right through a period of eight or ten days following operation, and in none of these 4 cases did the blood-pressure fall more than 6 points from what it originally reached at the end of the transfusion. To one we gave a second transfusion with the gum acacia. When this is combined with glucose, in certain of these alarming cases the effect is very marvelous.

I will mention one severe case of hyperemesis. The patient came in with a condition of great collapse, a blood-pressure of 90 systolic, and a low pulse-pressure. She was too ill to do anything with. We gave her glucose solution slowly. She had it throughout the whole night. Her condition was so greatly improved, although vomiting continued, that we were able to empty the uterus. The patient ran a very long convalescence; and she required repeated transfusions of glucose; she also was given transfusions of blood. Ultimately she made a complete recovery, and I am perfectly certain the patient never would have survived had we not had this means at hand for treating her.

One important thing in the gum acacia solution is the method of preparation. A great many bad results have been due to bad preparations of the gum. We must use a pure preparation of the gum acacia if possible, and the preparation of the solution must be carefully made. The water used must be freshly distilled water and the sterilizing of the solution in the autoclave must be carefully done. The solution can be put up in greater strength and kept in the operating room and rapidly diluted at the time when they are to be used.

I think it is most opportune that a subject like this has been brought before a large body of operating surgeons.

Dr. George Gray Ward, Jr., New York City.—The studies we have been making at the Woman's Hospital, as presented to you by Dr. Farrar, have been carried out with difficulty. Dr. Farrar has worked under the greatest handicaps. We found at first that we could not rely on the CO_2 estimations, with the Van Slyke method in our laboratory, in spite of having full-time laboratory men available, because of the great amount of work called for by the routine work of the hospital. For that reason, we obtained a technician from the Rockefeller Institute who made all these investigations so that they would be of unquestionable value.

The gum acacia solution, when we first tried it, was a failure from the fact that it was not properly prepared. It was not until we went to Toronto and saw it used there and got from Dr. Watson the exact technic in the preparation, which requires considerable care and many filtrations, that we had a satisfactory solution. There is no question in my mind as to the value and clinical effect of this method in cases of severe operation. The The patients show remarkable little reaction compared to the other cases, notably in those cases Dr. Farrar spoke of in which a Wertheim operation was done and attended with considerable shock. One of the important things you must understand is that the administration intravenously of gum acacia and glucose is given throughout the operation by a slow method, as pointed out by Dr. Woodyatt, who has devised a special apparatus. Unfortunately this costs three or four hundred dollars, and we could not get one, but we regulated the flow with needles and stop cock as well as possible, giving a slow continuous administration from the commencement of the operation. I think it might make a difference in the results if the solution was given very rapidly as one would give an ordinary saline infusion. Perhaps that may account for the differences Dr. Frank observed in the Army where they did not have the time for proper administration, but gave it as one would give the ordinary infusion. The high percentage used in the Army may have made a considerable difference also.

The combined use of gum acacia and glucose, as suggested by Erlanger, is theoretically correct, and from our cases it would seem to be borne out clinically, Our results confirm the findings of Cannon that the blood-pressure is a valuable index as to the CO_2 content, as regards acidosis. Instead of it being necessary to use the Van Slyke method, if we take the blood-pressure throughout the operation, we have all the time an index as to the degree of acidosis, which greatly simplifies the practical study of the problem. We used a bracelet stethoscope for that purpose and had readings taken during these operations.

The point that Dr. Woodyatt made is very important—that glucose energizes the muscle so that the muscle becomes tonic, as it were. This I think is shown in the rather free passage of flatus after the operation in these cases, stimulating the intestinal muscle, and there is also in addition quite a marked diuresis as one would expect.

I wish to confirm the point made by Dr. Watson in severe vomiting. We had that borne out in several of our cases, where we could not relieve the persistent vomiting until we gave glucose intravenously.

Dr. George Gellhorn, St. Louis, Missouri.—Is it possible to increase before operation the alkaline reserve of the organism to such an extent as to prevent acidosis?

Dr. J. Wesley Bovée, Washington, D. C.—I wish Dr. Farrar would give us a more definite expression as to the rapidity of the current in this slow process.

Dr. Joseph B. De Lee, Chicago.—How often do rigors occur after these administrations?

Dr. George W. Kosmak, New York City.—The method Dr. Farrar has described is undoubtedly a valuable one, but as a matter of practical application, would it be possible to substitute some other point of entry for the glucose?

I have for several years given glucose solutions by rectum after operation in doses from 6 to 8 ounces at intervals of two or three hours and believe I have had better results than with the use of salt solution for that purpose.

I would like to know whether in ordinary practice we cannot substitute the rectal administration of the glucose and whether it would not be of the same value for complications of this kind?

DR. LILIAN K. P. FARRAR, New York City (closing the discussion).—First of all, I want to thank Dr. Woodyatt for coming here and discussing this subject because it is really the physiologist upon whom we must depend to know what to put in a patient's blood.

Dr. Frank spoke about the results obtained in the Army in giving gum acacia intravenously. One must find out exactly what can be put in the blood before one can obtain good results and it is only with the help of the physiologist that this can be done.

One of the speakers said that he had used a 6 per cent. solution of glucose and that he had had only an occasional favorable result with it. I have kept to the 20 per cent. glucose because of Dr. Woodyatt's findings, and have been guided entirely in glucose feedings by his work in the laboratory.

It was found by a special investigation committee of Great Britain which did so much in trying out salt solution in hypertonic strength and bicarbonate of soda which Cannon advocated, that dilution of the blood was not a good thing, and, if long continued, was even harmful, and that there was no especial advantage to be gained by it.

The thing of real importance was to get a solution which corresponded to the viscosity of the blood and that is what 20 per cent. glucose and 6 per cent. gum acacia does.

That brings up the question of rigors and chills. We have not seen any in this series. Two patient's who were given glucose intravenously in the ward for acidosis by an intern who did not appreciate the necessity of keeping to the rate, although he had been told, did have chills, but these were not operative cases. There were absolutely no chills or rigors in the other cases. There has been absolutely no case of infection or necrosis of tissue and we have had no bad results of any description.

As to the question of putting up the solution in a higher strength and diluting it, a point brought up by Dr. Watson, we find it more convenient to put the solution in flasks of 250 c.c., that means 50 grams to the flask, which is what we can give the average patient in an operation of one hour.

The technic is simple. An apparatus, such as is used for giving salvarsan, is prepared. The stop-cock on the tubing regulates the rate of flow and an infusion thermometer in the tubing indicates the temperature which should be 105° F.

With reference to the question of absorption of the solution by rectum, glucose is not absorbed by the rectum faster than 1.8 gr. per hour. The great value of glucose lies in its introduction into the blood. It is not altered by the liver, it goes into the tissues, and it has a far greater effect than glucose put into the stomach or bowel.

As to the prevention of acidosis, which was spoken of by Dr. Gellhorn, I could not take it up in the limited time at my disposal. It is possible to do a great deal toward prevention of acidosis by proper feeding of the patient beforehand. We can bring the alkali reserve up by giving the patient a protein-free carbohydrate diet, and we can accomplish some good by the administration of bicarbonate of soda before the operation, but the great drop that occurs during the operation cannot be offset unless we do something at that time, and the beneficial effect is then directly upon the tissues themselves just as Dr. Woodyatt has said. Thank you for your kind attention.