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THE VISCOSITY OF THE BLOOD; ITS VALUE IN CLINICAL MEDICINE.*

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The peripheral resistance to the circulation of the blood is important in general pathology. On the degree of this resistance depends the cardiac energy required to maintain the circulation, as well as the tension of the circulating fluid, with its far-reaching influences on nutrition. Two factors dominate and control this resistance in accordance with well recognized physical laws. These factors are (1) the changing caliber of the arterioles, (2) the chemico-physical characters of the blood. That the first is much the more important there can be no doubt; but that the second, as indicated by its viscosity, is entitled to careful study will be evident on the slightest examination. Huerthle, for instance, calculated that the work done by the heart of the dog is more than four times as great as it would be if the blood vessels were filled with distilled water instead of blood. This difference is due to its viscosity, which is four and seven-tenths times that of water. In the human subject it is slightly greater, the average, according to Hirsch and Beck,¹ being 5.1.

There is not entire agreement among different observers as to the average normal viscosity of human blood. Determann² found it 4.7 in man and 4.5 in women, and Ewart³ even less. Kottmann, on the other hand, makes it 5.11, agreeing with Hirsch and Beck. My own observations, covering a considerable number of cases make it a little less than five. Physiologic variations are constantly occurring, and their limits are not yet definitely established. It appears to me that variations below 4.5 and above 5.5, if persistent, may well be regarded as abnormal.

Under pathologic conditions the viscosity has been found to vary from three to nine times that of distilled water. Such variations in the internal friction and cohesion of the blood must have a tremendous effect on the physics of the circulation; while the diagnostic and therapeutic problems suggested are of the first importance.

* Read in the Section on Practice of Medicine of the American Medical Association, at the Fifty-ninth Annual Session, held at Chicago, June, 1908.

1. Muenchener med. Wehnschr., 1900, xlvii, 1685; Deutsches Arch. f. klin. med., Leipzig, lxi, 503; Id., lxxii, 560; Arch. f. exper. Path. u. Pharmacol., Leipzig, liv, 54. The following references may also be consulted: Burton-Opitz, R.: Am. Med., Phila., 1900, vii, 111; Jour. Exp. Med., 1906, viii, 59 and 240; Abstr. Am. Med., N. S., i, 42; Arch. f. d. ges. Physiol., cxii, 189.

2. Verhandl. d. Congr. f. innere Med., Wiesb., xx, 476; Ztschr. f. klin. Med., lix, 283.

3. Brit. Med. Jour., Lond., ii, supplement, p. 10.

The volume of any fluid which will pass through a capillary tube, under given conditions is entirely dependent on its viscosity, and if the co-efficient of viscosity is known, can be calculated with mathematical exactness. Such a calculation, however, expressing the viscosity in absolute terms is obviously neither necessary nor practical for clinical medicine. As scientific physicians, however, we should understand the general principles on which these calculations are based, and these I will therefore briefly outline.

The factors which influence the rate of flow are the diameter and length of the capillary tube, the pressure applied to the fluid, and, finally, its viscosity. The smaller the diameter of the capillary tube the greater, relatively to the moving volume of fluid, becomes the surface in contact with the wall of the tube. The friction between these surfaces is one of the greatest obstacles to be overcome. Molecules of fluid in actual contact with the wall of the tube probably remain stationary, and the flow is entirely due to the intramolecular motion of the fluid, the rate of flow increasing toward the center of the moving column. Hence, the larger the lumen of the tube, the greater will be the velocity of the center of the moving stream, which means not only a greater absolute flow, but a greater flow relatively to the size of the tube. Thus the changing caliber of the arterioles influences the velocity and consequently the volume of blood flowing through them.

It is furthermore obvious that the longer the capillary tube of a given dimension the greater the friction. The length of the tube is, therefore, an important factor.

The rate of flow will also be directly influenced by its pressure. Under normal conditions blood flows through the arterioles under a pressure equal to that exerted by a column of mercury from 100 to 125 mm. in height. Other conditions remaining the same, the rate of flow will bear a certain definite ratio to the pressure.

Finally, the rate of flow of the fluid will be less the greater its viscosity. Viscosity is a physical property dependent on the freedom of motion between the molecules or particles which constitute the fluid. As in the case of blood, the fluid may hold in suspension solid particles (corpuscles) which will greatly influence the viscosity. Heubner calculated that two-thirds to three-fourths of the viscosity of the blood is due to the corpuscles. In some of the current literature the viscosity of the blood is expressed in absolute terms derived from calculations based on the data just given. Different mathematical formulas, based on Poiseuille's law, have been used for this purpose.

As Ostwald's physico-chemical measurements form the basis of most of the work along this line, I will quote the one used by him.

4. Ostwald: Physico-chemical Measurements.

The volume of liquid, v , flowing from a long capillary tube is $\frac{xpr t}{8cl}$, where x is 3.1416, p the pressure, r the radius, l the length of the tube, all expressed in millimeters, and t , the time, expressed in seconds; c is a factor depending on the nature of the liquid and on the temperature, and is called the co-efficient of viscosity. It is consequently found by means of the equation, $c = \frac{xpr t}{8vl}$, and is given in the absolute metric system if the pressure is expressed in ergs $\times$ cm.—3, the radius and length in cm., the volume in cc., and the time in seconds.

Such calculations as these are obviously too technical for clinical use, and are not at all necessary for the purposes of clinical medicine. What is needed is, first, some convenient uniform standard of comparison which will express the relative viscosity, and available at all times and places; and, second, a method for determining viscosity sufficiently simple in its character to make it practicable for routine examinations.

Such a standard is found in distilled water, and nearly all the work which has been done up to this time expresses the viscosity of the blood as so many times

paratus (1) attached to the standard by a clamp. The purpose of this jar is to immerse the apparatus in water at 38 C. so that the temperature conditions will not change during the observation. The measuring apparatus consists of the bent tube (2), the lower portion of which, including the ampulla (3), is filled with blood at (4) by removing the closed tube (5). The blood is drawn by suction through the capillary tube to the upper X, and is forced back by a uniform pressure to the lower X, the time required for traveling this distance under given conditions of pressure, temperature, etc., constituting the basis for comparison in making the necessary calculations.

Instead of using water Hirsch and Beck used freshly distilled anilin oil, the viscosity of which is known, but this requires a second calculation to reduce it to the standard of distilled water. The pressure, which is positive and not negative, as in my own method and that of Hess, is produced by the bulb (6) acting through the flask (7) and is regulated by the manometer (8). A tube of calcium chlorid is interposed to dehydrate the air before it comes in contact with the blood. Their observations are made under a uniform pressure of 450 mm. of benzol equal to 400 of water. It will be noted that this pressure does not even distantly approximate the physiologic pressure maintained in the circulating mammalian blood vessels. This usually exceeds 100 mm. of mercury, which would be equivalent to about 1,350 mm. of water.

The apparatus and method is too cumbersome and technical to fulfill the requirements above indicated, and after a little experience with it I set about to simplify the method. Absolute scientific accuracy is not required in any clinical investigation of this sort. Determann admits a possible technical variation of two-tenths to five-tenths of a second with the same apparatus, same blood and the same operator. It is largely a question of accuracy of co-ordinating two distinct movements at the same instant of time, and it requires considerable practice to avoid an error of a considerable fraction of a second. Furthermore the physical condition of the blood and therefore its viscosity is undergoing constant fluctuations depending on the amount of food and liquid absorbed, perspiration, urinary secretions and probably many other factors, concerning some of which we know little or nothing. Approximate results easily and quickly attained were therefore the objects in view.

The principle of forcing the blood through a given length of a capillary tube under definite pressure and temperature conditions and comparing the time with that which it takes to force distilled water through the same tube under the same conditions appeared to be the only fundamental requisites. The exact size of the capillary tube is not important, and really varied considerably in the appliances used by Hirsch and Beck, Ewart, Determann and others. Poiseuille, for instance, used tubes varying from .139 to .659 mm. and Hirsch and Beck tubes varying from .25 to .35 mm.

As a result of my investigation I am now using the very simple appliance⁶ shown in Fig. 2.

It consists of a capillary pipette (3) made from a piece of glass tubing with a lumen of 5 mm. One end is tapered (4) so that the rubber bulb (2) can be fitted over it easily. The other end is drawn out into a fine

Fig. 1.—Hirsch and Beck's viscosity apparatus as modified by Determann, Bence and others.

that of distilled water, even though giving along with it the results of the technical calculations above referred to which express it in absolute terms.

The original investigations by Poiseuille, dealing with the viscosity of the blood were made with defibrinated blood. While having a scientific interest, this method involves such a wide departure from physiologic conditions as to be devoid of clinical interest. Huerthle was the first investigator to use the uncoagulated blood of the lower animal. To Hirsch and Beck, however, belong the credit of making a practical application of the data and methods of Huerthle and preceding investigators to the requirements of clinical medicine. Their apparatus which was subsequently modified by Determann, Bence⁵ and others is shown in Figure 1. It consists of a glass jar 4x7 inches and 10 inches high, which contains the measuring ap-

5. Ztschr. f. klin. Med., Berl., lviii, 203.

6. This is much simpler than the apparatus that I showed at the Chicago meeting, as I have been able to eliminate the T-shaped glass tube with rubber tubing and clamp, which makes it less cumbersome.

capillary tube, the exact size of which must be determined by experience. This is substantially the same as the capillary pipette used in opsonic work. A convenient length for the capillary portion of the tube is about six inches, and it should be made so that distilled water will pass through it under the negative pressure of the bulb in about five or six seconds. A blue pencil, or, much better, a fine ink mark is made at (5) just before the lumen of the capillary tube begins to enlarge, and each experiment terminates at the moment when the moving column reaches this mark.

The first thing to do is to "standardize" the tube with distilled water which constitutes the unit of comparison. The rubber bulb (2) is taken between the thumb and index finger of the right hand and compressed until its inner surfaces are in contact. It is important that this technic should be accurately followed. If this is done, there will not be any substantial variation in the negative pressure of the same bulb in different experiments. If, however, the bulb is compressed flatly between, say, the palmar surfaces of the thumb and two fingers, the pressure will be increased from forty to fifty per cent. and the results entirely vitiated.

The precise negative pressure will vary with different bulbs. With the one that I am working with, which measures $1\frac{1}{2} \times 2\frac{1}{2}$ inches and is taken from a 10 c.c. volumetric pipette in my clinical laboratory, it is equal, approximately, to 50 mm. of mercury. Within reasonable limits the exact pressure is unimportant, so that it

Fig. 2.—The author's viscosity apparatus.

is the same with the blood that it was with the distilled water.

This bulb thus compressed is fitted over the capillary pipette at (4) and the pressure released. Air flows into the capillary tube under a constant negative pressure. With a stop-watch in the other hand, the end of the pipette is immersed in distilled water contained in a watch crystal and the stop-watch started at the same instant. The watch is stopped when the column of water reaches the mark at (5). This is repeated three or four times, and if there is any variation the mean of the several observations is taken and a label attached to the tube showing the result and also the temperature of the room.

The temperature of the room is important because the viscosity falls about two per cent. with each degree centigrade of rise of temperature, and if the observation on the blood is made at a temperature substantially different from that in which it was standardized with distilled water, corresponding corrections must be made.

The capillary tube can be made so that it takes distilled water anywhere from three to six or seven seconds to reach the mark; about five or six seconds is the most convenient and practical time, and a little practice will enable one to make the pipette of the proper size. If it takes too long, break off a little of the pipette, if not long enough a new one must be made.

The clinical observation is made as follows: One arm of the V-shaped tube, made of glass tubing with a

lumen of $1\frac{1}{2}$ mm. is partially filled with blood by holding it against the under surface of a drop exuding from the side of the tip of the finger, as I prefer, or the lobe of the ear. Five or six drops of blood are required. This tube is then held by an assistant or in a suitable clamp by the arm through which the blood has been collected, leaving the clean arm of the tube for observation. The bulb and capillary tube are arranged precisely as above described for the experiment with distilled water and the end of the capillary tube passed down the clean arm of the V-shaped tube until it is close to the surface of the specimen of blood. Then with the stop-watch in the other hand it is quickly plunged into the blood and the stop-watch started at the same instant, the watch being stopped, as before, when the moving column reaches the mark at (5). It is then simply a matter of dividing the time required by the blood to pass through

Fig. 3.—Hess' viscosity apparatus.

the capillary tube, by the time required by the distilled water, which in the pipette illustrated was five seconds. If with this pipette it would take twenty-five seconds for the blood to reach the mark the viscosity of the blood would be just five.

This observation can be made in less than three minutes, and is, in my opinion, sufficiently accurate to serve the purposes of clinical medicine.

Sometimes the blood coagulates so rapidly that only a single observation can be made. This can be obviated by placing a crystal of hirudin in the V-shaped tube, as recommended by Bence and Determann. The blood will then remain fluid for twenty or thirty minutes. The greatest objection that I have found to the use of

hirudin is that it is very hygroscopic and must be kept hermetically sealed or in a chamber with a desiccator. Its use, however, is quite unobjectionable, as it does not change the viscosity in the least or even modify rouleaux formation, so that it is available for other purposes in which slow coagulation is desirable as well as the determination of viscosity.

The capillary tube is cleaned in the usual way, first by washing with distilled water then with alcohol and finally with ether, and drying with a current of air. Should the tube be spoiled, as often happens, it only costs a fraction of a cent and a few minutes' time to make another.

The apparatus of Hess (Fig. 3) represents another attempt at simplification. I have neither seen nor used it, but believe that my own is simpler and more practical. With Hess's apparatus distilled water must be used at the same time with the blood (which complicates the procedure) and the two are drawn through their respective capillary tubes presumably by a negative pressure, the source of which is not shown in the illustration.

CLINICAL APPLICATION.

As already indicated, the viscosity of the blood under normal conditions undergoes considerable fluctuations owing to a variety of causes, among which may be mentioned the ingestion of a large quantity of water or food. Heavy muscular work has also been found to increase viscosity. Possibly by the increased transudation of fluid through the skin the same effect results as follows a sweating by electric light and other hot baths.

These variations will be readily understood when the factors which influence viscosity are taken into account. Among these the percentage of blood corpuscles is perhaps the most important, which Heubner, as already stated, calculates is accountable for the greater part of its viscosity. It has been clearly shown, however, that there are constituents in the plasma which influence it very much. It is probably in some way connected with the fibrin, as it has been found that the viscosity and coagulability increase and diminish together within certain limits.

The inhalation of chloroform and ether has no effect on viscosity. Alcohol, on the contrary, immediately and greatly increases it. This has been found to be the case whether alcohol was introduced into the circulation intravenously or by injection either into the stomach or duodenum. This experimental fact is of considerable importance in the pathology of chronic alcoholism and may help to explain some of its phenomena. The immediate effect of hemorrhage is to greatly lower the viscosity of the blood. This effect is quite lasting, contrary to that of the intravenous infusion of normal saline solution which also lowers viscosity, the effect being very evanescent, however.

The diminished viscosity of the blood following venesection very probably has much to do with the well known therapeutic results in the way of relieving an embarrassed heart, etc., under certain pathologic conditions. There is no doubt whatever that it greatly lowers the resistance in the peripheral circulation, as well as the volume of the circulating fluid.

Asphyxia influences viscosity more promptly and more profoundly, perhaps, than any other known factor. This is true whether the asphyxia is local or general. In one experiment, for instance, Determann found that by placing a ligature around one arm for twenty min-

utes, with the production of marked local stasis, the viscosity of the blood drawn from a finger on that side was nearly twice as great as in blood from the other arm. It had increased from 4.63 to 8.83.

These are among the most important observations made along this line. Their influence in pathology is far reaching. They clearly show why the heart becomes embarrassed, and raises a doubt as to the exact importance of vaso-constriction under such conditions, although it is, of course, quite possible that this may occur also. The direct effect of CO₂ in increasing the viscosity has not only been experimentally demonstrated, but Bence has actually lowered it again by the inhalation of oxygen, an observation which is also of great importance.

The clinical application of these facts is probably not limited to the acute conditions of cardiac embarrassment in which life is endangered, and in which venesection and the inhalation of oxygen are clearly shown to be indicated, but probably extends to the subacute or chronic conditions of respiratory incapacity.

An interesting observation of Determann, confirmed by others, is that in vegetarians the viscosity was materially lower than in meat eaters. The average for vegetarians was 4.32 and for meat eaters 4.85. As might be expected, the viscosity of the blood is low in the anemias. In a fatal case of splenic anemia under my observation the viscosity was less than 3. The red corpuscles had dropped to about 200,000 before the patient died.

One of the important questions concerning viscosity is its relation to Bright's disease and especially to the cardiac hypertrophy found in these cases. The question is exceedingly complex and not nearly so easily solved as might at first sight appear. There seems to be little doubt that when the average case of Bright's disease presents itself for clinical observation to those who were studying the viscosity of the blood that the latter was nearly always normal or low, and this without very much reference to the blood pressure at the time. In my own experience the viscosity has usually been between three and four, but every case was more or less anemic. The observations of Bence were to the same effect.

Hirsch and Beck studied twenty-four cases which were divided into three groups as follows: The first group included acute and subacute parenchymatous cases in which the following viscosities occurred: 5.29, 2.75, 4.28, 3.81, 2.92. The second group, chronic parenchymatous nephritis, with secondary contractions, contained the following: 4.87, 4.24, 4.26, 4.79, 4.74, 3.05, 3.42, 2.52. The third group, chronic interstitial nephritis, with primary contractions, showed: 5.91, 4.70, 4.89, 9.21, 4.52. It is interesting to note that the lowest viscosity in the entire series, namely, the last case in the second group, with a viscosity of 2.42, had a blood pressure of 242 mm. In three of the twenty-four cases the viscosity was above the average normal standard adopted by Hirsch and Beck. It is distinctly stated that in neither of these three cases was there any marked hydremia.

Herein lies the explanation of the comparatively low viscosity found so constantly in Bright's disease, for we usually have, as was found in twenty-one out of twenty-four of these cases, a more or less marked anemia. This anemia means, of course, a reduction in the number of

erythrocytes on which, as pointed out by Heubner,⁷ the viscosity very largely depends.

Just what would be found in the pre-anemic stage of Bright's disease, if these cases could be observed at this time, is a question which is not yet settled, and in its very nature is almost impossible of solution. Few diseases are so insidious in their development, so completely masked in their early stages as this, and, as a rule, when first seen the blood has undergone serious changes and has become more or less hydremic. Ewart contends that the viscosity is high at this time and is one of the factors in the production of the cardiac hypertrophy. Hirsch and Beck, supported by Bence, controvert this view, and claim for reasons that do not appear to me entirely conclusive, that increased viscosity is not a factor in producing the cardiac hypertrophy. The difficulty lies in observing the cases early enough to determine the conditions during the early stages of the hypertrophy, which is usually well marked when the case is recognized.

As shown by Determann, Hirsch and Beck and Bence, those who eat considerable quantities of meat have a higher viscosity, and in at least one of the series of cases above quoted in which there was no anemia, the viscosity was extremely high. When the effect of a free meat diet is taken in connection with alcohol, together with the toxic conditions which we now believe to be antecedent to the fully developed picture of Bright's disease, high viscosity appears to be probable in the preliminary stages. Just in so far as it does exist must it be reckoned with as a factor, although very possibly a subordinate one, in increasing the work of the heart, the physiologic result of which is hypertrophy.

In the cases with arterial disease the high resistance in the peripheral circulation is much more important in increasing the work of the heart and with a very low viscosity may give us a high blood pressure, as in the case above quoted. It seems to me, therefore, that while the effect of the toxins on the heart muscle may reasonably be regarded as an excitant of over-action on the part of the heart and consequently of hypertrophy, as originally set forth by Bright, that it is strictly in accordance with clinical and scientific data to regard an increased peripheral resistance both from a diminished caliber of the blood vessels and an increased viscosity as important factors in the production of the cardiac hypertrophy of Bright's disease. Just how large a rôle increased viscosity plays and in what group of cases it is most conspicuous it is impossible at present to say.

Not very much can yet be said concerning the therapeutics of high viscosity. The iodids undoubtedly modify it in some way, and are therefore indicated in suitable cases in small doses. In cases of polycythemia the treatment is that of the blood condition. In several cases under my observation with viscosity sufficiently high to form important factors in circulatory disturbances this condition was present in a very marked degree. In one case with a red cell count of 7,250,000, the viscosity was very nearly seven. There was associated with the polycythemia, hyperchlorhydria and neurasthenic symptoms. During a month's treatment in the hospital, along with the general improvement, the red cell count gradually dropped to about 5,000,000 and the viscosity to 5.5.

The obscure modifications of the plasma which undoubtedly influence viscosity can only be treated in a general way by improved nutrition, elimination, etc., as their precise character is entirely unknown. The withdrawal of alcohol and a reduction or withdrawal of meat in the diet is clearly indicated in these cases. The importance of a free supply of oxygen is also clearly indicated by the experimental work with asphyxia and the inhalation of oxygen. Outdoor life, moderate exercise, the best of hygiene and everything that tends to uplift the physical condition of the patient should and usually will tend to lower excessively high viscosity and thus free the peripheral circulation.

A low viscosity usually means simple hydremia the therapeutic indications of which are plain enough, though not always effective.⁸

CONCLUSIONS.

1. The viscosity of the blood is an important physical property dependent on both the corpuscles and the plasma which furnishes a considerable part of the peripheral resistance to the circulation of the blood.
2. It undergoes considerable fluctuations as a result of physiologic changes connected with food, drink, exercise, etc.
3. Under pathologic conditions, the changes are much greater and the viscosity may be so much increased, as, for instance, when the blood is charged with CO₂, that the heart will be embarrassed in overcoming it.
4. The viscosity of the blood is actually low in the large majority of cases of chronic Bright's disease owing to existing hydremia, but there is probably an earlier stage with high viscosity.
5. It seems probable that an increased peripheral resistance in the circulation of the blood due, in part, to increased viscosity, is at least one of the factors in the production of the cardiac hypertrophy of Bright's disease.
6. Venesection greatly lowers the viscosity of the blood by withdrawing its solids and attracting the fluids from the surrounding tissues.
7. Alcohol introduced into the circulation greatly increases viscosity, and in this way interferes with the peripheral circulation and burdens the heart.
8. The approximate determination of the viscosity of the blood as a routine clinical procedure is desirable in nutritional and toxic disorders, and should be made by a method rapid and simple enough to be practicable for routine use.
9. Individual diseases do not change viscosity in any characteristic way except as they incidentally modify the blood.
10. The determination of viscosity should be made promptly before the corpuscles have time to settle, for obvious reasons. The use of hirudin, if it leads to considerable delay, is therefore objectionable unless the homogeneous mixture of plasma and corpuscles is again reproduced.
11. The viscosity of the blood is not altogether dependent on its specific gravity, for in fevers the former may be high and the latter very low.

ABSTRACT OF DISCUSSION.

DR. HENRY B. HEMENWAY, Evanston, Ill.: I believe the subject of Dr. McCaskey's paper to be one of the most important ever brought before the attention of the general practitioner. Dr. McCaskey, however, has kept the heart especially

7. Arch. f. exper. Path. u. Pharmacol., Leipz., liv, 149; Id., liii, 280.

8. Lommel, F.: Deutsches Arch. f. klin. Med., Leipz., 1904,

in view, whereas I have been looking especially at the general circulation. For example, pure water would flow for a long time and uninterrupted through a pipe of a certain size. If the water is impure, however—as, for example, sewage from the kitchen sink—the greater viscosity would clog the pipe. So, with increased viscosity of the blood there would be an obstruction to the circulation through the capillaries, and this tends to produce a closure in the capillaries. An interesting point is that, before the absolute closure, the arterial pressure is much greater than the venous pressure and there is the tendency for the serum to get into the tissues. This exuded fluid then gains an entrance back into the circulation by absorption through the small veins and lymphatics. This results in a gradual straining out of the organized elements of the blood and, in such cases, one would find an increasing anemia.

This increased viscosity of the blood, as well as sometimes an increased coagulability of the blood, is found in certain forms of Bright's disease and other conditions. Coagulability of the blood does not always accompany an increased viscosity of the blood. Yet there are times when the coagulability is accompanied by increased viscosity of the blood.

If the coagulability and the viscosity of the blood are increased at the same time, there is an inclination toward the production of a thrombosis, a thrombosis occurring in any portion of the body. So in this there is one of the most common conditions concerned in the production of thrombotic apoplexy. In the production of an attack of this form of apoplexy there is an increased viscosity, a slowing of blood current, with an increased coagulability of the blood which tends to produce thrombosis.

DR. NATHAN ROSEWATER, Cleveland: The viscosity of the blood has interested me for a long time. Viscosity of the blood is reduced by the iodids; this does not require very large doses, only from five to ten grains. The method Dr. McCaskey used I believe to be a good one; but would it not be practical to drop the blood directly from the pipette through alcohol or ether, noting the time, dropping it through a long column of the fluid?

DR. J. F. HULTGEN, Chicago: With regard to the relation between alcohol and the viscosity of the blood, Dr. McCaskey has omitted to give the dose administered, the kind of alcoholic beverage used, and as to whether there were any other morbid conditions coexisting at the time of alcohol ingestion. Moreover, he has not suggested how it does produce this increase in viscosity.

DR. LOUIS FAUGERES BISHOP, New York: The difficulty with which the blood circulates has a distinct relation to the increased red-cell count. In my experience there is a large number of cases of circulatory troubles in which high tension exists, cases occurring in overnourished people suffering from high arterial tension; the red-blood count has been considerably above 5,000,000. I have learned to expect the red-cell count to be above the normal in a certain type of cases.

Again I could expect the condition to improve with a reduction in the red-cell count by suitable hygiene. This shows to me that the red-cell count has an important bearing in certain conditions.

DR. G. W. McCASKEY, Fort Wayne, Ind.: In regard to the point mentioned by Dr. Bishop, an estimation of the red-cell count is certainly important. I am glad to hear Dr. Bishop say that in some cases of polycythemia the red-cell count dropped with improved hygienic conditions, for this is in accord with my experience. I do not know how alcohol acts on the viscosity of the blood. Twenty minutes after its introduction into the duodenum of animals there occurs an increased viscosity. Just what the change is I do not know. The experimental dose is from 5 to 20 c.c. I believe that the iodid of potassium lowers the viscosity of the blood. In studies on the viscosity of the blood I believe that we have found a partial explanation of how the iodids act in chronic cardiovascular diseases. As the viscosity is lowered, peripheral resistance is diminished.

SOME PHYSIOLOGIC ASPECTS OF BLOOD-VESSEL SURGERY.*

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INTRODUCTION.

The subject of blood-vessel surgery is not new. For many years surgeons have occasionally been called on not only to repair traumatic or pathologic injuries in the walls of arteries and veins, but also to unite the ends of cut vessels. An excellent review of the literature has been given by Murphy.¹ Among recent investigators and successful operators in this field, two of the leaders whose methods and results are known to all are present to-day. I refer to Drs. J. B. Murphy and Rudolph Matas. Their success has been due primarily to their refined technic, which essentially comprises the admixture of judgment and skill together with the employment of instruments and materials in accordance with the structures operated on. Dr. Tuholské tells me of successful results he has obtained by suturing blood vessels. No doubt there are other surgeons present who could likewise demonstrate successful results. Since success in this field has been achieved by a number of gentlemen present, it is with some trepidation that I present my views.

METHOD.

The technic employed in my experiments is a modification of that developed by Dr. Carrel and myself. Essentially it is the same as that employed by previous successful investigators in that it consists of gentle handling of the vessels, with protection from drying, smooth approximation of the intimal surfaces and fixation by means of needles and thread in proportion to the size of the vessels.

After exposing the vessel, temporary occlusion is obtained by means of ordinary serafine or bulldog forceps. By shielding the blades with muslin and forcibly compressing the springs to weaken them, the forceps may readily be adapted for use with liability of the vessel to injury reduced to a minimum. The edges to be sutured are cut smoothly with small sharp scissors. Excess of blood is removed by stripping the vessel between the fingers from the point of occlusion to the cut end and the blood absorbed with a soft dry sponge. The loose connective-tissue coat is then slightly stretched by grasping between the thumb and finger and snipped off even with the ends of the vessel. To protect the vessel from drying it is coated inside and out with paraffin oil. Two or more ligatures are then passed through corresponding points on the circumferential margins of the two ends of the vessel and tied, thus approximating the cut surfaces. The walls are then further united by a continuous suture entirely encircling the point of union, each stitch passing through the intima on either side a little way from the cut edge. The chief difference in the methods for arteries and veins is that in arteries the stitches are placed somewhat closer together than in veins. To facilitate handling and to aid in restraining coagulation, the threads are kept in paraffin oil. The

* Read in the Section on Surgery and Anatomy of the American Medical Association, at the Fifty-ninth Annual Session, held at Chicago, June, 1908.

1. Murphy, J. B.: Resection of Arteries and Veins Injured in Continuity End-to-End Suture, *Med. Rec.*, Jan. 16, 1897.