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REMARKS

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AND ON THE

SELECTION OF FLUIDS FOR INJECTING INTO THE VEINS.

BY

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ASSISTANT-SURGEON AND LECTURER ON ANATOMY, ST. THOMAS'S HOSPITAL.

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THE following remarks were put together a year ago but not published. They are founded upon cases of transfusion in surgical rather than in obstetric cases, but the principle insisted upon—that of the use of a natural and determinable force—applies equally to all cases. The subject had occupied my attention for some time after seeing many cases of severe surgical hemorrhage from injury, and being then in charge of the surgical in-patients at St. Thomas's Hospital, as Resident Assistant-Surgeon, I had an apparatus made by Messrs. Maw and Son, upon the principles which seemed to me most advisable. Shortly after this an opportunity was afforded me of putting these principles to the test.

On April 28, 1872, a woman, Elizabeth A., aged twenty-five, was admitted into hospital with both legs crushed from a railway accident. She had apparently lost a great deal of blood before admission, and was bleeding when brought to the Hospital, so that no time was lost before operating. Both legs were amputated below the knee, but during the operation upon one limb the femoral artery was so imperfectly held as to allow of rather extensive hemorrhage. The arteries were twisted.

Before the operation she was sensible, but evidently suffering from the shock of the injury, to some extent modified by free use of brandy. The temperature was 98°, not low for the shock of hemorrhage. However, she had been brought about two miles to the hospital, and a good deal of brandy had been administered on the way.

After the operation the temperature was 96°, and she was so much collapsed that I feared she would die on the operating table; a tourniquet was therefore placed on each of the main arteries of the limbs after emptying the veins as much as possible by friction towards the trunk. She became, however, so restless and cold, and her pulse became so feeble that I determined to transfuse, and opened the median basilic vein for the purpose.

Nearly six large teaspoonfuls of condensed milk were mixed with a pint of hot water and strained through muslin. This fluid was placed in the apparatus which I had had made a short time before, and this apparatus connected with the canula in the vein. Precautions were taken to keep the milk at the same temperature as it was at first made (100°).

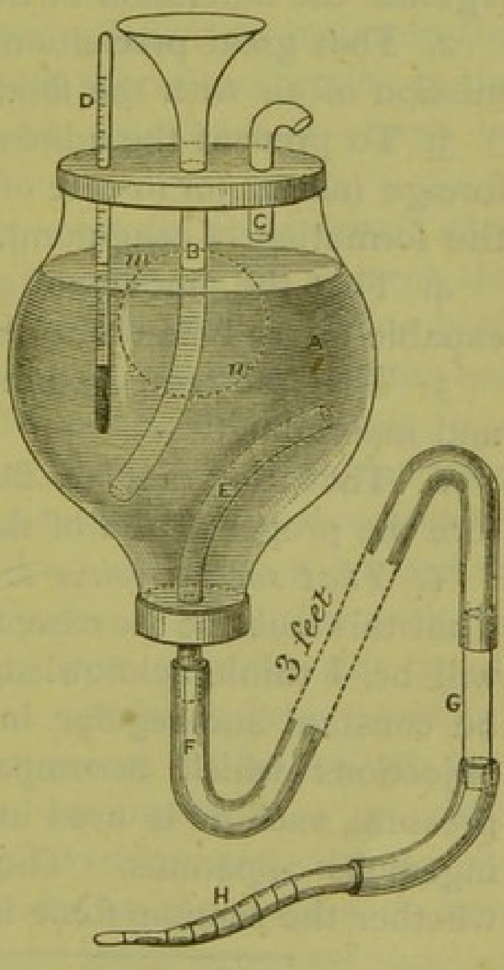
On starting the stream the milk flowed readily into the vein, and for the greater part of the time the suction power of the vessels was sufficient to continue the flow; at other times a little pressure was employed by raising the apparatus six inches above the level of the veins. During inspiration the flow was rapid; when she was crying out there was some regurgitation of the fluid. A pint and a half was injected.

The effect produced immediately was to contract the pupils (they had been previously dilated and inactive), then they fluttered but soon they became normal in size and acted under the stimulus of light. The temperature in the vagina before transfusion was 97° (2 A.M.). After transfusion 99°·1 (4.40 A.M.) and one hour again after this, 99°·8 (5.40 A.M.).

When I left her at six A.M. she was sensible, talking reasonably but rather restless, and I anticipated that she would improve. It appears that about half an hour after this she became weaker, more restless, and sighing, but her temperature was apparently not much lowered, for the sister of the ward noticed that the skin was comfortably warm. She died a little before 8 A.M.

At the post-mortem examination the viscera were found healthy. In this case there appears to have been a combination of shock and hemorrhage, both to a serious extent, so that it is difficult to judge how far the case was one likely to be permanently benefited by transfusion. But seeing her condition after operation, and knowing that she had lost an unusual quantity of blood, I deemed it justifiable to transfuse. For some time I had determined to give milk a fair trial as a substitute for blood in transfusion, having seen the ill effects of the latter (the lungs blocked with pulmonary clots). The results of transfusion of milk were not in this case permanently satisfactory, but they were satisfactory to this extent, that the patient was revived for a few hours, and that no ill results followed in the way of pulmonary clotting. The case was not one of pure hemorrhage, and I am inclined to believe that the shock of the injury, plus the shock of the double amputation, was the cause of death rather than hemorrhage and its consequences.

The apparatus used consists of a glass cylinder (A) capable of holding about half a pint of fluid, closed above by a large cork; the under surface of which is coated with gutta-percha. Through the centre of this cork passes a tube (B), funnel shaped above, for receiving the fluid, and carried below to near the bottom of the apparatus and to one side. Another small tube (C) passes through the cork in order to allow of the escape of air from the cylinder during the filling of the apparatus. A thermometer (D) has its index projecting also above the instrument.



The lower end is closed similarly by a coated cork which is perforated by the outflow tube (E), starting from the opposite side to that of the termination of the inflow tube and a little above it.

To this is attached a tube of india-rubber (F) about three feet long and coated with cotton wool. Near the end of this tube is a small piece of double glass tubing (G), to allow of the current of the fluid being observed.

The nozzle (H), which is inserted into the vein, is probe pointed and has its hole about ½ inch from the extreme point, so as to allow of its being partially withdrawn in order to clear the hole if necessary without removing the nozzle. It is notched above to insure the ligature biting and to prevent its slipping.

The cylinder (A) is encased in a wicker or other frame which is packed with cotton wool,* but a window is left opposite the dotted lines (*w*, *w*), to allow of the height of the fluid being observed.

The principles upon which the apparatus just described depends, are—

1. That suction rather than artificial pressure should regulate the admission of the fluid.

2. That great precaution is advisable to prevent the admission of air with the fluid.

3. To prevent the admission of solid sedimentary or other foreign matter (or in case of Blood to hinder as far as possible the formation of coagulum).

4. That the amount of artificial pressure used should be capable of ready estimation.

5. That the temperature of the liquid should be indicated and maintained.

6. That the rate of flow should be known, and therefore the proper action of the apparatus determinable.

1. *That suction-power is preferable to artificial pressure.*— That this must be the case, if only sufficient to procure a flow, will be, I think, acknowledged by all, for such a force would be constant and regular in action, and not exposed to the objections which accompany an unknown and artificial pressure, such as is used in a simple syringe, or in Aveling's ingenious apparatus. The only question which arises is, whether the suction force is sufficient to promote the flow of

* I have it now covered with india-rubber as more convenient, and the window made as a vertical slit.

fluid into the vein. It would appear from the case narrated above in which this instrument was used, that the suction-power in the vein was not sufficient to commence the flow, probably owing to the walls of the vein lying in contact with one another ; or possibly to the presence of a small clot against the orifice of the canula, but that immediately this was dislodged by slight extra pressure, the flow continued regularly for a considerable time. It must be noticed that no pressure whatever was used during the greater part of the time, but that when the flow became less active, during the latter part of the trial, pressure was made by raising the instrument a short distance (6 inches).

It is evident, therefore, that the suction-power in the vessels is sufficient in a case of collapse due chiefly to hemorrhage to maintain a steady in-take of fluid (to the extent of about a pint in this case) and that very slight pressure was sufficient to give a start to it, and also to increase the quantity taken in to about a pint and a half.

Now if the suction-power proves sufficient to maintain the flow in such a case as that described, the sole objection to the use of this means—that of possible insufficiency—must be disposed of.

2. It is needless to point to the necessity for extreme care in the use of any apparatus for transfusion, to prevent the admission of air. I have had the opportunity of seeing both instantaneous and slow death follow in cases where air has passed into the veins. In one case the femoral vein was opened, and death was almost immediate : in the other case the lingual vein was half divided, and death was slow, occurring in the course of about an hour. In both cases the blood in the right side of the heart was frothy. To avoid such an accident it is, I imagine, necessary that a transfusion apparatus should be made to work as continuously as possible ; no parts of it should have to be removed to be refilled, &c., and the supply to it should be as constant as possible. These objections apply to a simple syringe, and also to the simple funnel, while they are avoided in the apparatus here described ; that is to say, the cylinder being kept well supplied with fluid, never being allowed to be emptied below a certain

line, there will be no possibility of air entering the vein while the vessel is kept upright, and the flow will be regular.

3. If artificially prepared liquids are made use of for transfusing, there is, of course, a possibility of sediment passing in with the fluid, and forming a focus for coagulation, or mechanically obstructing the passage of blood in the lungs. The risk of these dangers is to be avoided by carefully preparing the fluid, straining it through muslin, and allowing it to stand a short time ; but to diminish the risk as much as possible, the outflow tube from the cylinder is made to come from a short distance above the bottom of the apparatus. By this arrangement, and by carrying the supply tube to the opposite side, and to near the bottom, the orifice of the outflow tube is also kept in fluid which is comparatively still, not thrown into a state of turmoil by the incoming fluid, and therefore less liable to receive foreign matters and sediment which might otherwise be stirred up.

If defibrinated blood be transfused, the dangers of coagulation would, of course, be almost entirely avoided ; but if fresh blood be used, the chief source of danger would be the formation of clots and the carrying off of these into the circulation. Now, whatever apparatus is employed, that portion of the blood which comes into contact with the walls must necessarily coagulate, since blood is coagulated by contact with a foreign body, as Prof. Lister showed in his Croonian Lecture before the Royal Society. Therefore, whether a syringe, or funnel, or india-rubber bag, or this apparatus be used, blood will clot against the surface of the instrument. But this is of comparatively little importance compared with the danger of detaching the clot. In fact, the formation of a thin layer of clot against the walls is the best preventive against further deposit ; for blood in contact with clot does not coagulate as readily as against any other foreign material that we are likely to use. What we have chiefly to consider is how best to avoid disturbing the clot when formed, and this can only be done by an apparatus in which there is a minimum of disturbance in the fluid. Such a condition cannot be found in a syringe or funnel, and in Aveling's india-rubber compression-bags the disturbance must be at a maximum.

4. It must at times be necessary to use artificial pressure in order to start the flow, and in order sometimes to enable the operator to supply a larger volume of fluid than will be sucked in naturally. It may be that a small clot forms at the orifice of the insertion tube, and has to be displaced. It must be displaced, if it be there, before the flow can commence; but cannot we diminish the risk of entire dislodgment and consequent embolism? The force of a piston, or of the pressure of the hand on the compression-bag is an undeterminable one, and who knows what injury may be done by it? But the pressure of a column of fluid is a determinable one, and, moreover, it is a steady one; and it is quite possible that a clot, if formed, may be only partially dislodged, and allow the passage of fluid which was prevented until the apparatus was raised (as in the case narrated) to the height sufficient to allow of the amount of pressure necessary to overcome the obstruction.

There may be, I imagine, a source of obstruction to the first passage of the fluid in another condition. It may be that the vein above the point at which the instrument is inserted has collapsed, either from the pressure exercised during the operation or from the loss of blood from the system, or both combined, and I can understand the possibility of initiatory pressure being requisite for this reason. I would not exclude this as an explanation of what occurred in my own case above narrated. But after this initiatory pressure has been rendered unnecessary, and the suction-power of the vessels is sufficient to continue the flow, it would be irrational to keep on a pressure which is not wanted.

My objection to the ordinary apparatuses is especially in respect to this point. They employ artificial pressure, either entirely (as in the piston) or not at all (as in the communicating tube between two veins), and if entirely they do not provide the means of estimating the force used. It is difficult to estimate the harm which may be done by the employment of such rough means, and even with the greatest care on the part of the injector it is, I conceive, unlikely that ill results will be avoided. The pressure, if it be excessive, as it is almost certain to be, must distend the veins to an injurious extent; an excess of fluid is thrown into the right side of the heart, which the pulmonary circulation, as it then stands, has not made way for, and rupture of veins, with over-distension of the right side of the heart, and consequent hindrance to its contraction, may follow. It was seen in the case detailed above that the flow varied with the respiration, a fact which is familiar enough to physiological experimenters, and no provision can be made for this variation in rapidity when artificial pressure is given by means of a piston or a compression bag, but it is allowed of when the moving power is suctional, and even when the apparatus I have described is slightly raised, so as to give extra pressure.

In this instrument I have added only three feet of tubing, and therefore the means of giving pressure equivalent to about a pound and a half to the square inch, but of course it would be possible to increase the pressure to any extent by adding to the length of the tube. By lengthening the tube, however, the chances of cooling the fluid would be increased, and the case in which the apparatus was used led me to consider that more than this pressure would rarely be required.

5. In order to preserve the temperature of the fluid, whether it be blood or artificially prepared, the different parts of the apparatus must be enveloped in some non-conducting material, like cotton wool, and a thermometer in the cylinder indicates the actual temperature, which will, of course, be slightly diminished by radiation below; but certain parts must be left exposed, so that the progress of the current and the working of the apparatus can be properly under observation. For these purposes, a window* must be left in the material enveloping the cylinder, and a piece of double glass tubing may be attached to the lower end of the india-rubber tube, and this can be connected with the insertion pipe by means of a small piece of protected elastic tubing, like that used above the glass. The object of this glass tubing is to enable the operator to watch the flow of the liquid, and a clip can be placed on the india-rubber below it at any time, if necessary. The outer glass tube is in order to provide a coating of warm air to the inner, and diminish the amount of cooling by radiation.*

* I have now done away with this piece of glass tubing, since the vertical slot in the cylinder-casing shows the flow clearly.

There is a point with reference to the insertion pipe which is worthy of notice. In several cases I have found it advantageous to know exactly the distance to which the canula has been inserted, and have therefore had it marked at definite distances from the end, just as on the uterine sound. These markings are moreover useful in allowing the ligature to hold the canula fixedly in position, without a risk of its slipping, and the bulbous end insures the tube not leaving the vein. The opening should be on the upper side.

Class of Cases in which Transfusion is likely to be Serviceable.—Transfusion has been employed with beneficial effect in two kinds of cases. 1. Those of collapse from hemorrhage. 2. Those of collapse from loss of the watery and saline constituents of the blood, as in cholera. These two classes of cases are alike in the effects produced, but differ entirely in the cause, the first being mechanical, while the second is the result of the presence of a special poison. In the first, as seen simply in post-partum hemorrhage, or complicated with nervous shock in most cases of surgical hemorrhage, we should be led to replace the lost blood by more blood, for something more than the watery constituents have escaped. But with blood, as I have remarked before, special precautions have to be taken, and we are safer in avoiding the use of ordinary blood, provided other suitable fluids are obtainable. Blood, moreover, is generally difficult to obtain on a sudden emergency, and there is often, and perhaps generally, no time to defibrinate it. However, if blood be made use of, it should be deprived of its fibrin, in order to diminish the risk of embolism, and with the defibrinated blood should be mixed some material which has in it the elements necessary for not only immediately imparting warmth, but also sustaining the heat of the body.

In the second class of cases, where a great drain of fluid from the blood has produced collapse, as in cholera, we should be led to expect better results from simple saline injections into the veins ; but do we find this ? Experience proves the contrary, for the relief, though marked, is only transient ; and the explanation of this is probably to be found in the presence of the poison still in the blood. It is not to be supposed that the repeated injections of warm salines will destroy this poison, nor is it likely that they will make up for the injury done to the corpuscles themselves, which must be looked upon as the active elements of change in the nourishment of the tissues. But these injections will give temporary relief by supplying the blood with fluid to replace that which is lost, and by giving that warmth which the arrested healthy changes of nutrition have failed to maintain. Something more, however, is wanted, and this is undoubtedly the point to which our attention must be directed in preparing artificial fluids for transfusion. We have to find something which shall not only at once give warmth, and so relax capillaries, which, in the skin at least, are firmly contracted, and promote chemical change in the vessels and tissues; we have to find something which shall also give the means of sustaining that warmth. Such material must, I think, be looked for in one of these classes of compounds—the albuminous, the saccharine, or the oleaginous, or of course, in a combination of these. Given such a material we may reasonably hope for success, for if animal heat can be maintained by such artificial means, time will be given for the destruction or elimination of the poison producing the fatal symptoms. Transfusion of such material in this class of cases would effect this—it would supply fluid, it would supply immediate warmth, and it would afford the means of sustaining that warmth.

Character of Fluid Transfused.—The requirements for this fluid appear to be (1) warmth; (2) power of sustaining animal heat (by combustion in the blood, and especially in connexion with respiration); (3) miscibility with the blood already in the system without injurious effects, either mechanically, as by coagulation, or physiologically by what we may term poisoning.

We have especially to remember that the fluid must be readily procurable and simple, not requiring elaborate preparation. In cases where transfusion is resorted to there is usually no time to be lost, and if it be possible to employ satisfactorily some fluid which is to be found always at hand, it may be the means of preserving life. This consideration compels us to bear in mind two or three natural productions to the exclusion of artificially prepared fluids. Blood and milk are especially suggested, for one or other is sure to be obtainable—blood probably from some friend, or milk at all events.

Blood has been used effectually long before now, but there is no doubt a grave objection to it in the danger of embolism from formation and detachment of clot from some portion of any apparatus. That danger is, however, reduced to a minimum by the use of the instrument I have described, since the fluid is maintained without unnecessary disturbance.

Blood may be of course prevented from coagulating by the addition of various salts, and it might be suggested that such a modification would afford a valuable material for transfusing. I should expect, however, that the amount of salts necessary to prevent coagulation would act detrimentally, either by promoting a too rapid osmosis, or by interfering with nutrition and normal chemical change, or by physiologically poisoning.

Blood, again, may be defibrinated, but this process is too long to make the use of this fluid generally available. Moreover, there are cases, as I have pointed out above, where something more than blood is required—an actual heat-supporting fluid, and in these blood alone must not be expected to do more than temporary good.

Milk appears to offer all the requirements of a fluid for transfusing. It may be passed in warm, and so give immediate warmth. Its composition is such as to anticipate it will maintain the heat of the body. It is, moreover, miscible with the blood without injurious effects ; in fact, it is possible, according to Ryneck, to cause the circulation of milk to the exclusion of blood in the frog, and not interfere with the vitality of the tissues. In the case narrated in this paper condensed milk was made use of, and purposely, for I considered that fresh milk was more likely to coagulate, and was more liable to possess impurities than the condensed. It may be interesting to notice here that condensed milk may be exposed to the air, even in a moderately damp cupboard, for more than a year without destroying its character. As soon as the surface is removed the condensed paste is to be found below, of course, usually more inspissated, but capable still of producing cream, on the surface of a solution which has been allowed to stand four-and-twenty hours. I do not mean to recommend exposed milk for such an object as transfusion, but if a solution be made of the ordinary condensed milk, so as to resemble new milk, it will be suitable for use. It is advisable to strain the milk through muslin to get rid of any mechanical impurities, and then may be used either alone or mixed with other materials, such as blood, or defibrinated blood, or ammonia, if a stimulant be required, &c. We have reason to believe that the only constituents of milk are absorbed without special change, *i.e.*, as oily particles, in combination sometimes with albuminous material, but such is not the case probably with the soluble albuminous constituents of food. We should have, therefore, more hesitation in mixing with any transfusion liquid strained solutions of meat, egg, &c., not knowing what disturbance they might produce, or even how far the necessity for them was indicated. Milk contains a certain proportion of albumen (which is not got rid of by condensation), and it is by its other constituents, saccharine and oleaginous, especially pointed to as the appropriate fluid for transfusion.

Since writing the above, I have had an opportunity of seeing how far a mixture of blood and milk can be relied on as a non-coagulable fluid. Equal parts of freshly drawn defibrinated blood and warm milk (prepared by mixing condensed milk with twelve times its quantity of water) were put together, and used with the transfusion apparatus. The mixture passed readily, and no clotting occurred, and some of it was kept in an uncorked bottle for a week in hot weather (August, 1873) without decomposition or coagulation. The blood used was obtained from the arms of three dressers, who volunteered their services, in the hope of relieving a patient who had, however, gone too far for recovery. It was a case in which nervous shock had been very great in addition to extensive hemorrhage, but taken in conjunction with the first-narrated case, it was of some small value in showing that surgical hemorrhage with nerve shock is a much more serious condition than simple hemorrhage. There was no response to the transfusion in this case, though more than a pint and a half was injected. Seeing the results obtained in these two cases, I should feel inclined in another case to add ammonia to the material injected, in the hope, somewhat faint though it be, that the stimulant would rouse the depressed nervous system.

If transfusion is to be of any practical value, it must be ready of application, and both the apparatus and the fluid must by readily obtainable.

There is no reason, it seems to me, why each of these requirements should not be fulfilled. A jug standing in a bason of hot water to keep the fluid warm, a piece of tubing hanging out of the jug as a syphon, or fitted on a smaller tube, or a crow-quill, which is to be tied in the vein, constitutes all the machinery necessary ; the length of the tube and the height at which the jug is placed give the means for all the pressure required. For the fluid, if blood can be obtained so much the better, and let it be defibrinated and mixed with warm milk ; if not, let warm milk be used alone, or with some stimulant. Such apparatus and fluid ought to be readily applied, but this will depend on the sagacity of the operator and the worth of his assistants. Special apparatus will save time, but the probability is that it will not be at hand when wanted, and therefore impromptu measures may have to be used. If an apparatus be used, risks of injury to the patient ought to be avoided, and therefore an undeterminable force ought, I think, to be excluded if possible. By a simple apparatus like that which I have suggested, force, if necessary, can be used, but it is accurately determinable, every foot of height representing about half a pound of pressure.