spending time and trouble over them. Such is far from being the case, and the suggestion of the Medical Research Committee, that the issue, in estimating efficiency, is confused if the presence of a systolic murmur is noticed at all, does not appear to me to be a sound one. Every murmur is well worthy of attention, and those which can be classified as negligible should be noted as such. A knowledge of the nature and significance of the different types will lead to a reasoned conclusion as to how much weight should be attached to each. Diastolic murmurs have always a serious significance, and systolic murmurs are often associated with grave disease. But many systolic murmurs are negligible, and the general recognition of this truth will free a considerable section of the community from a needlessly restricted life, and from a cloud of unnecessary and haunting apprehension.

REFERENCES.

¹ The Linacre Lecture, 1915 (BRITISH MEDICAL JOURNAL, January 26th, 1916, p. 122). ² 1917, pp. 8 and 32.

TRANSFUSION WITH PRESERVED RED BLOOD CELLS.

BY

OSWALD H. ROBERTSON, CAPT. M.O.R.C., U.S.A.,
U.S. ARMY BASE HOSPITAL.

THERE is a definite need in front area medical work of a method for giving transfusions rapidly. At casualty clearing stations during the busy time of an attack, it is obviously impossible to perform transfusions by the usual methods in nearly all the cases in which transfusion is indicated. The difficulty of procuring sufficient blood under rush conditions, the time consumed in carrying out the transfusions, and the need of every available medical officer in the operating theatre, all tend to reduce the number of transfusions which can be given. The use of preserved human blood cells for transfusion suggested itself as a possible solution of certain of these difficulties. A quantity of blood sufficient for a number of transfusions could be stored up beforehand and used as needed. The technique of transfusing such blood is simple and could be handled by one medical officer.

History of the Subject.

The experimental basis for this work was laid by Bous and Turner¹ working at the Rockefeller Institute for Medical Research. They found that blood taken into a solution of dextrose and sodium citrate and kept in the cold could be preserved for several weeks. Not only did the red blood cells thus treated remain intact, but they retained their viability for a long period. The preserving fluid used consisted of 5.4 per cent. dextrose combined with 3.8 per cent. sodium citrate; both of these solutions are isotonic with blood plasma. The optimum proportions of blood and dextrose citrate solution were found to be as follows: Three parts of blood, two parts of citrate, and five parts of dextrose solution. This mixture was placed in the ice chest and the red cells allowed to sediment. The supernatant fluid showed no signs of haemolysis even after the red cell layer had been stirred up repeatedly. Furthermore, after washing these cells in Locke's solution, there was no evidence of loss of integrity. It was found that the rabbit's blood preserved in this way could be kept intact for three to four weeks, and sheep's blood for as long a period as eight weeks. Human red blood cells showed no apparent deterioration at the end of four weeks. They determined the viability of preserved blood cells by means of transfusion of these cells in bulk. Rabbits were used for this purpose. A normal rabbit was bled a large quantity, up to half its blood volume, causing a marked drop in the haemoglobin percentage and red cell count. Immediately afterwards the rabbit was transfused with an amount of preserved rabbit's blood cells equal to the amount lost in bleeding. The haemoglobin returned promptly to its previous level. The animal showed no ill effects from the procedure, and the haemoglobin and red cell count remained normal. This demonstrated that the transfused preserved blood cells were behaving as normal red corpuscles. By this means it was found that rabbit's blood could be kept living for two weeks. Many similar experiments were carried out with the same result. Parallel tests were made with blood cells kept for longer periods. Rabbits were bled a large quantity as before and immediately transfused with preserved blood cells kept three weeks or more, but which still showed no signs of haemolysis. There was a prompt return of the haemoglobin to normal after the transfusion. This condition, however, was only temporary. The red cell count and haemoglobin soon began to fall, and by the end of the second day the transfused cells had practically disappeared from the circulation, leaving the rabbits markedly anaemic. The animals seemed normal

otherwise—that is, there was no apparent harmful effect from the transfusion of intact preserved blood cells kept beyond the period of their viability. On the other hand, the transfusion of preserved blood cells that were beginning to show haemolysis had an extremely harmful effect, and the recipients died often within twenty-four hours. At the necropsy evidence of marked haemolysis was found.

An opportunity to test the usefulness of this method of transfusion with preserved human red blood cells was afforded me by the medical authorities of the Third Army, B.E.F., at whose casualty clearing stations the work was carried out.

METHODS.

1. PREPARATION OF THE PRESERVING SOLUTIONS.

The solutions of dextrose and sodium citrate are made up on the basis of 500 c.cm. of blood, as this is the usual amount taken from a donor. This requires in round numbers 350 c.cm. "isocitrate" (isotonic sodium citrate solution) and 850 c.cm. "isodextrose." These two solutions must be made up and must be autoclaved separately. Freshly distilled water should be used for all solutions.

For the preparation of "isodextrose" powdered dextrose is preferable, but since this substance is no longer obtainable in any quantity liquid glucose is used instead, and thus far has proved satisfactory; 2 grams of the liquid glucose is equivalent to 1.6 grams powdered dextrose. Thus, to make up 850 c.cm. of a 5.4 per cent. solution, 46 grams of powdered dextrose or 57.5 grams of liquid glucose is needed. On account of the difficulty in weighing out and dissolving liquid glucose, it is convenient to make up a large quantity of a 20 per cent. solution. This can be used as a stock from which the "isodextrose" may be prepared. Enough stock for six lots of "isodextrose" is made by dissolving 360 grams of liquid glucose in sufficient distilled water to bring the total volume of the solution to 1,800 c.cm. It is then filtered through coarse filter paper. If the solution is to be kept it should be sterilized. For making "isodextrose" 287 c.cm. of this concentrated solution is diluted with distilled water to 850 c.cm. in a clean two-litre bottle (Winchester). The bottle is stoppered with a cotton-wool plug, which is covered with gauze and tied on. The solution is sterilized in the autoclave for one half-hour at a temperature of 105° C. (equals 3 lb. steam pressure). This temperature should be reached slowly, as bottles of this size are liable to break if the change of temperature is rapid. For this purpose a one-burner Primus lamp is suitable. Care should be taken that the temperature does not exceed 105° C., as glucose may decompose if heated above this point.

There are no difficulties in preparing the 3.8 per cent. sodium citrate solution, but it is convenient to make up a 20 per cent. stock solution. A quantity sufficient for six lots of "isocitrate" is prepared by dissolving 90 grams sodium citrate in distilled water to a volume of 450 c.cm. and filtering. If this concentrated solution is to be kept it should be sterilized. For making "isocitrate," 66.5 c.cm. of the 20 per cent. solution is diluted to 350 c.cm. with distilled water. These 350 c.cm. amounts are sterilized in small bottles of the size used for transfusing the blood (described later). The same precaution is taken to cover the mouth of the bottle as in the case of the glucose solution; 105°–110° C. in the autoclave for one half-hour is sufficient.

2. PROCURING THE BLOOD.

(a) Donors.

Persons belonging to blood group IV² only are used. This saves the necessity of doing agglutination tests before transfusion, since blood cells of this group are not haemolyzed or agglutinated by the blood of any individual. The writer has not had the slightest difficulty in getting volunteers for donors. The importance of transfusion is explained to them beforehand and they are told that it is now possible to keep blood for some time and have it immediately available when needed. The donors are chosen from among patients with trivial wounds or those who have recovered from slight wounds. Persons giving a history of malaria, trench fever, or syphilis are excluded.

(b) Apparatus.

The apparatus for bleeding and the method of measuring are shown in Fig. 1.

The Winchester bottle containing the sterile isodextrose serves as the bleeding bottle. Before mixing the solutions

a mark is made on the bottle at the upper level of the dextrose solution, A; 350 c.cm. isocitrate is then poured in and another mark made at the new fluid level, B. The distance A-B measures 350 c.cm., which is roughly two-thirds of 500 c.cm. A third mark is made at C, a distance

FIG. 1.

above B equalling one and a half times the distance A-B. This measures approximately 500 c.cm.

The chief points about the apparatus are these:

The needle (A) should be of a large bore—1.5 mm. diameter was found to work well—and not more than 1.5 in. long. It should have a fairly large olive-shaped base. The needle is the most important part of the apparatus, and requires careful attention. Before each bleeding it should be carefully sharpened. The most important consideration in the sharpening is to produce a good spear-point. If the point is well protected when not in use by a metal barrel or piece of rubber tubing, sharpening will require only a moment or so. The needle must be kept scrupulously clean, and after each bleeding should be washed out at once, all fragments of fibrin or clot removed from the base, and small pieces of cotton-wool soaked in liquid paraffin thrust through the lumen with the stilette. The whole needle is well oiled before being put away.

The rubber connexion (B) should be flexible, and not more than 3 in. long. The inner surface should be smooth, and the lumen slightly smaller than that of the glass inlet tube (C). If the rubber connexion fits snugly over the base of the needle, tying it on is not necessary.

The glass inlet tube (C) is made of a large-bore glass tubing about 6 mm. internal diameter. It should extend below the level (B) of the solution in the bottle.

The glass tubing and the stopper are dry sterilized. The needle and attached rubber connexion are boiled for ten to fifteen minutes before use.

(c) Procedure of Bleeding.

The donor's arm is extended at a right angle to the body. The skin of the antecubital space is scrubbed with soap and water and the sterilization completed with alcohol. A tourniquet is applied to the arm high up and a suitable vein chosen, remembering that the needle is to be inserted towards the hand. It is very important to have as large a vein as possible. Opening and closing the fist and flicking the skin below the point chosen for venipuncture aids much in dilating the veins. At the point selected to puncture, a small amount of novocain is injected intracutaneously. The tourniquet is then released. The apparatus is assembled as shown in the diagram, great care being taken to keep all the open parts sterile. Sufficient pressure is made with the pump to fill the system with solution. When the air has been driven out of the needle, the stopcock on the connecting tube is closed. The pump-bulb is reversed so that suction can be made when needed. The apparatus is now ready for use.

The tourniquet is again tightened sufficiently to make the veins stand out well, but not enough to obliterate the pulse. The cuff of a blood pressure apparatus makes an excellent tourniquet with a pressure kept at 50–60 mm. A small nick is then made through the skin with the point of a scalpel. The bottle is placed on a stand close to the patient's arm in such a position that there will be no kinking of the rubber connexion when the needle is in the vein. Slight suction is next made in the bottle. The

skin opening is mopped dry with a piece of sterile gauze and the needle inserted for a short distance beneath the skin before entering the vein. The stopcock is then opened and the needle is pushed into the vein immediately. The blood follows the column of solution down the tube without leaving an air space. A moderate degree of suction is maintained and the donor continues to open and close his hand slowly, care being taken that he does not move his arm. It is essential to keep the needle immobile. The operator should hold it throughout the bleeding, steadying his hand against the donor's arm. With these precautions 500 c.cm. of blood can be easily and quickly obtained.

If clotting occurs for any reason, such as the needle slipping out of the vein or air leakage, and the blood ceases to flow, the tourniquet should be released, the stopcock closed, the needle withdrawn from the vein, and another attempt made with a fresh apparatus (needle, rubber connexion, and glass tube) using the same receiving bottle. It is usually better to take another vein.

It is not necessary to agitate the bottle until after the bleeding. When the 500 c.cm. mark has been reached the tourniquet is removed, the stopcock closed, and the needle withdrawn. The bottle is then given a gentle rotary motion in order to mix the blood thoroughly with the preserving solution. After this the rubber stopper is removed and the original cotton plug, which has been kept sterile, is replaced. The blood is labelled with date, quantity, and name of donor, and placed in the ice-chest to sediment.

If the donor's veins are small and the needle method fails, the vein can be cut down upon and a cannula used. Inserting a cannula into a vein is more difficult and time-consuming than the needle method, and offers greater possibility for infection.

The glass tubing, rubber connexion, and needle are cleaned thoroughly immediately after the bleeding. The donor is kept on the table for fifteen to twenty minutes in order to avoid the feeling of faintness which may be caused by getting up at once. The withdrawal of this amount of blood—500 c.cm.—has no harmful effect.

In order to give transfusions of varying amounts it has been found convenient to procure quantities of 250 c.cm. of blood as well. For this purpose quart bottles are used in place of the Winchester, and contain half quantities of the glucose-citrate solutions. It is best to bleed 250 c.cm. from each arm, using a fresh suction apparatus for the second bleeding.

3. STORING THE BLOOD.

An ice-box is necessary for storing the blood. A suitable one can be improvised. The box, made of wood, should be double-walled with an air-space between. Two packing cases fitting one inside the other serve the purpose well. The space between the two boxes is filled with sawdust or some such non-conducting material. A tight-fitting door or lid is necessary. It is well to line the inside box with tin, and one end of this space should be fenced off to contain the ice.

This large bulk of blood, 500 c.cm., settles rather slowly. The supernatant fluid increases at the rate of 150 to 200 c.cm. a day. This is one real objection to the method, since it means that the blood is not available for immediate use. However, at the end of four to five days the blood will have settled to about 800 or 900 c.cm., and can then be used, as this amount of cell suspension does not contain any more sodium citrate than is given in an ordinary citrate transfusion. The additional fluid and sugar solution is an advantage rather than otherwise. Smaller quantities of blood, 300 and 400 c.cm., when taken into the same amount of preserving fluid that is used for 500 c.cm. of blood, settle more quickly, and could be used at the end of three or four days. If there is an indication that blood will be needed soon, 300 c.cm. amounts may be collected in place of the usual 500 c.cm., and the sediment of two or more bottles combined for a transfusion.

The supernatant fluid seen through the green thick-walled bottle has a slightly opaque bluish-white appearance. This opacity is due chiefly to blood platelets in suspension. Sometimes it has a yellowish or yellowish-green appearance if the blood plasma is highly coloured. Occasionally a scum of fat collects at the surface. This is of no significance. A pink tinting of the supernatant fluid

should be regarded with suspicion as it signifies haemolysis probably due to infection. Such a blood should be discarded. This has not occurred in the present work thus far, but has been seen experimentally. Cultures of the supernatant fluids have all been negative. Occasionally the supernatant fluid shows a pink tint during the first two or three days of sedimentation, which gradually disappears. This is not haemolysis. It is due to unequal settling of the red cells. A thin suspension of cells remains above the main bulk of the blood and sediments more slowly. Beginning disintegration of the red cells may occur at the end of the fourth week of keeping, and is marked by a pink colouring of the supernatant fluid just above the cell layer which soon increases in intensity and rises toward the surface. This blood, of course, should be thrown away as its use would be dangerous.

4. TRANSFUSION OF THE BLOOD.

(a) Preparation of the Blood for Transfusion.

The supernatant fluid is drawn off by means of a siphon apparatus shown in Fig. 2. The glass tube and stopper are sterilized either by dry heat or boiling. The tube is placed in the bottle so that its lower end reaches almost to the blood layer. Suction by mouth is made at the end of

FIG. 2.

the rubber tube, which need not be sterile. The only precaution necessary is that the liquid should be sucked up steadily and the suction released only when the column of fluid has reached the glass connexion (A), which is below the bottom of the bottle.

If the blood has been stored for some time the cells may have sedimented to a volume below that of the original amount of blood withdrawn. In this case a diluting fluid is added to bring the volume of a cell suspension at least to that of the original amount of blood. A 2.5 per cent. solution of gelatin in normal saline* was used for this purpose, on the theory that such a solution would remain in the circulation much longer than salt solution alone.

The blood cell suspension is then gently agitated by a rotary motion, and poured through two layers of sterile gauze into the transfusion bottle described below (Fig. 3). Filtering the blood is necessary because occasional small clumps may form during sedimentation. The gauze is tucked into the wide-mouthed bottle with a pair of sterile forceps. The bottle is tilted slightly so that the blood flows down the side instead of falling to the bottom, which might injure the blood cells. The bottle is restoppered and placed in a glass jar containing water at a temperature of 106° to 107° F. If the water is maintained at this temperature, and the bottle is occasionally agitated, the blood becomes warm in a few minutes.

* This is Hogan's solution slightly modified. It is most easily prepared as follows: 25 grams of purest quality gelatin (gold seal, finest quality) are dissolved in 200 c.cm. distilled water, to which is added 2 grams of NaCl. The mixture is boiled for fifteen to twenty minutes in a water bath to bring about complete solution of the gelatin. It is then filtered while hot through coarse filter paper (Chardin agar)—preferably in a hot filter—and autoclaved for one hour at 124° C. When desired for use, the gelatin is melted in warm water and poured into 800 c.cm. of sterile 0.9 per cent. NaCl solution to which has been added 0.2 per cent. sodium carbonate—Na₂CO₃ (10 H₂O). The water used for this solution should be freshly distilled.

(b) Apparatus.

The apparatus for transmission is shown in Fig. 3. A wide-mouthed quart bottle is chosen for giving the blood, the stopper and neck of which should be protected before sterilization by a gauze covering. The needle employed has a bore about half the size of that used for bleeding. The length is not important. As shown in the illustration, the needle is attached to a short glass tube by means of a small piece of rubber tubing. The free end of the glass tube is thrust into the end of the long rubber tube (b) after the needle is in the vein. The rubber tube (b) may be of any convenient length. The glass tube (c) is bent so that the end projects into the lowest part of the bottle. In this way almost every drop of blood in the bottle may be given. The needle, with connexions (b) and (c) and the stopcock, are boiled up before use. The remainder of the apparatus is dry sterilized.

(c) Procedure of Transfusion.

The recipient's arm is prepared in a manner similar to that described for the donor, and a small amount of novocain injected into the site chosen for the vein puncture. The apparatus is assembled according to the diagram in Fig. 3. The bottle is kept in warm water during the entire process. It is well to tie the rubber stopper down to the bottle with two strips of adhesive plaster in order to prevent it from flying out when the pressure increases. After these preparations have been completed sufficient

FIG. 3.

pressure is put on the pump to fill the apparatus with blood, and the stopcock is closed. The tourniquet is then tightened. As soon as the needle enters the vein blood flows out through the short glass tube, the tourniquet is immediately released, the apparatus is connected up, the stopcock opened, and the pump started. This technique is simple, and, if carried out carefully, there is no danger of forcing air into the vein. If the veins are collapsed or constricted, as is the case with certain patients in shock, it may be necessary to cut down on the vein and use a glass or silver cannula instead of the needle.

By using a needle it is scarcely possible to force the blood in too rapidly. With a cannula care must be taken to go slowly. Ten minutes should be the minimum time for the introduction of 500 c.cm. of blood. Care should also be taken to close the stopcock before the air bubbles begin to pass up the tube.

RESULTS OF TRANSFUSION.

The blood used for transfusion had been kept varying periods of time up to twenty-six days. The majority of the transfusions were given with blood preserved from ten days to two weeks. The patients transfused included cases of haemorrhage, shock, and sepsis—chiefly the two former. An attempt was made to choose only those cases who would probably die without transfusion and yet who had a chance of recovery if given blood—that is, the only moderately serious and the apparently hopeless cases were excluded. (Indications governing the choice of cases for transfusion will be discussed in detail in a subsequent paper.) The amounts given in a single transfusion varied from 500 c.cm. to 1,000 c.cm., depending on the type of case. If the condition was one of

marked anaemia the blood sediments of two large bottles were combined. Where the anaemia was less severe a large bottle and a small one—750 c.cm.—were given. In cases judged to be chiefly shock 500 c.cm. amounts were used. The total fluid bulk of the transfusion, as before stated, was always made up to 1,000 c.cm. with gelatin solution.

The effect of transfusion with preserved blood was fully as striking as that observed after the giving of freshly drawn blood. There was the same marked improvement in colour, the pulse became slower and stronger, and the blood pressure showed an increase of 20 to 40 points. Furthermore, this improvement was maintained and increased. Patients transfused before operation stood the operation procedure well, and subsequent progress was quite as good as in those cases transfused by the usual methods.

Haemoglobin estimations* were made before and after transfusion, and in certain cases the red cells were counted as well. It was hoped that these determinations would give fairly accurate information as to the length of time the preserved blood cells remained in the circulation. The results of the tests, however, were inconclusive in many cases on account of the progressive fall in haemoglobin per cent. which occurs after acute blood loss and shock. Haemoglobin estimations after transfusion with fresh blood showed variations identical with those occurring after preserved blood cell transfusion. In some instances there was a rise of 5 per cent. to 20 per cent. afterwards, which was maintained during the time the patients were under observation—periods of from two to eight days. In other cases the haemoglobin per cent. showed a temporary increase after transfusion, followed next day by a drop to the previous level, or in one or two instances to a point even lower than it had been before transfusion. Still others showed very little change in the haemoglobin following transfusion. These findings had no apparent connexion with the length of time the blood had been kept previous to transfusion.

There were no reactions either during the giving of the blood or afterwards. The only possible exception to this was in a case of gas gangrene who complained of slight chilliness and shivered a little immediately after transfusion, which very soon passed off without other symptoms.

No evidence of increased blood destruction after transfusion was observed. The urine was studied for three to four days subsequent to transfusion in patients who had received blood kept nine to twelve days. Spectroscopic tests for haemoglobin and urobilin were negative except in two cases who developed gas gangrene two to three days after transfusion when a faint trace of urobilin appeared in the urine. Tests for bile made by the nitric acid method were negative. Unfortunately it was not possible under the conditions obtaining to test the urine of patients transfused with blood kept for longer periods than twelve days.

In all, twenty-two transfusions were given to twenty individuals. Of these, eleven were discharged to the base in good condition and nine died—a mortality of 45 per cent. Those patients who later died all showed the immediate stimulating effect of transfusion with one exception, a case of profound anaemia who died just after transfusion. Four died within forty-eight hours, of gas gangrene; and four lived from two to six days, dying ultimately from the same cause. Three of the four patients in this last mentioned group showed very marked improvement subsequent to transfusion; they stood operation well and were making satisfactory progress several days afterwards when gas infection appeared.

The length of time the blood had been kept appeared to have no influence on its beneficial effect. The improvement in those cases transfused with blood kept three weeks or more seemed to be just as marked as in those who received blood preserved for much shorter periods. It is probable that four weeks represents about the limit to which blood can be kept for transfusion, as the red cells usually begin to disintegrate soon after this. Judging by the experimental results quoted in the beginning of the paper, it will do no harm to inject blood cells kept beyond the period of their viability provided they are still intact,

but much benefit cannot be expected from such a transfusion.

The criticism may be raised that blood deprived of its plasma cannot be as efficient a restorative as whole blood. In conditions of low blood pressure due to shock the plasma is probably a valuable part of the transfused blood. For this reason gelatin solution is added to the red cells in order to approximate more nearly the normal consistency of blood. However, in cases of simple exsanguination, the red blood cells alone are probably quite sufficient to restore the circulation to its normal condition. Abel, of Johns Hopkins, has shown this experimentally by removing large amounts of blood from dogs and replacing only the corpuscles suspended in Locke's solution. Bleedings were repeated in the same animal until all his plasma had been replaced by Locke's solution. The animal suffered no apparent ill effects from the procedure.

ADVANTAGES OF PRESERVED BLOOD CELLS FOR TRANSFUSION.

The chief value of this method lies in the convenience of having a large quantity of blood on hand for a rush. Just before a recent attack the writer laid in a store of twenty pints of blood, which furnished sufficient material for fourteen transfusions. During the first two or three days of the fighting it would have been difficult to give transfusions in the usual way, not only on account of the time element involved, but also because of the scarcity of donors. This was due to the fact that the casualty clearing station at which this work was done received at first an unusually large proportion of the more seriously wounded, the slightly wounded being sent further on. As donors are picked from among those with trivial wounds the immediately available supply was small. This state of affairs became apparent when the stock of preserved blood had been exhausted, which occurred on the third day. It was then necessary to resort to "immediate" transfusions, and much time was consumed in finding suitable donors.

Another marked advantage is the time saved in giving the transfusions. The procedure can be carried out in a relatively short space of time by one medical officer and an orderly assistant. The technique is simple, and can be acquired easily.

The blood can be given at the bedside. A patient in shock may be considerably injured by carrying to the operating room or even lifting him out of bed on to a table near by. Furthermore, under rush conditions it is a great convenience to be able to do a transfusion without the necessity of having the donor and recipient together. Another consideration is the operating room space saved by giving the transfusions in the resuscitation ward.

It is possible by this method to give a large amount of blood in a single transfusion. This is particularly desirable in cases of severe anaemia. Very often it is not feasible under the conditions existing during an attack to give large "immediate" transfusions because of the fact that the withdrawal of amounts of blood greater than 600 c.cm., or at most 700 c.cm., from donors who are frequently suffering from varying degrees of exhaustion, may weaken them to an unjustifiable extent. In those cases of marked anaemia who were given preserved blood cells a single transfusion of 1,000 c.cm. was sufficient, while similar cases transfused with 500 to 600 c.cm. of fresh blood not infrequently needed a second transfusion.

Fluid may be added to the preserved blood cells before transfusions to any amount desired. In conditions where the circulation has been depleted, the introduction of a large quantity of a suitable fluid is indicated. Solutions of gelatin or gum acacia serve this purpose best. It was found that transfusions of large fluid bulk obviated the necessity which might otherwise arise of a subsequent injection of fluid or even of a second transfusion.

During periods of only moderate activity, when there is no need of a large store of blood, it has been found very convenient to keep a small quantity of preserved blood on hand for use at night. This has two advantages: One is the time saved; the other is avoidance of the difficulty which may arise in finding a suitable donor at night, as it is not always possible during busy times to keep a list of Group IV donors in reserve.

Transportation.

It has been found possible to transport preserved blood cells for a considerable distance. On several occasions

* Haemoglobin tests were made with a modified Sahli haemoglobinometer.

bottles of sedimented blood were carried in an ambulance for six or eight miles over rough roads without any damage to the cells. There was a slight stirring up of the surface of the sedimented layer, which coloured the supernatant fluid to a moderate degree. Judging by the colour, this contained perhaps 10 c.cm. of suspended blood cells, not more. Thus, if the blood had been used immediately after transportation, very little would have been lost in the siphonage. On standing, the blood cells soon settled, leaving a clear fluid above. It was considered possible that the red blood cells below the surface might have been injured during transit and the resulting haemolysis concealed in the deeper layers. Accordingly, the whole sediment was thoroughly stirred up, then allowed to sediment. As before, the supernatant fluid showed no sign of haemolysis.

SUMMARY.

As first found by Rous and Turner, it is possible to preserve living human red blood cells for several weeks in a solution of dextrose and citrate, when kept at ice-box temperature. This method of keeping blood has been made use of recently for giving transfusions at casualty clearing stations during a rush period. A quantity of blood was stored up beforehand ready for use when needed. The blood was kept for varying periods up to twenty-six days before transfusion. Twenty-two transfusions were given to twenty cases by this method. The majority of these were cases of haemorrhage. The results of preserved blood transfusion were quite as striking as those seen after transfusion with blood freshly drawn. There was the same marked improvement, the patients stood operation well, and subsequent progress was quite as good as in those cases transfused by the usual methods. The introduction of kept red blood cells had no apparent harmful effect, as there were no reactions or evidence of increased haemolysis after transfusion.

The chief advantage of this method over other methods of transfusion in current use is the great convenience of having a stock of blood on hand for busy times. The transfusions can be given relatively quickly, and the technique, which is simple and easily acquired, can be carried out entirely by one medical officer.

Experiments in the transportation of preserved blood have shown that it can be carried a considerable distance without injury.

REFERENCES.

- ¹ Peyton Rous and J. R. Turner, *Exper. Med.*, 1916, xliii, 219. ² Major R. I. Lee, *BRITISH MEDICAL JOURNAL*, November 24th, 1917. O. H. Robertson, "Transfusion at Casualty Clearing Stations" (not yet published).

BLOOD TRANSFUSION IN A FIELD AMBULANCE.

BY

CAPTAIN NORMAN M. GUIOU, C.A.M.C.

THE work described in this article was undertaken as the result of lectures delivered by Major McNee and Captain Sladden, R.A.M.C., and Major Harrison, C.A.M.C., and is an endeavour to show that the operation of blood transfusion is *easily* applicable to the forward area, where it is most needed.

Group Testing.

As the mobile laboratory was busy preparing serums for casualty clearing stations, a few cubic centimetres of II and III serums were obtained from the Lister Institute. A group of dressers of different sections was assembled and shown the macroscopic test as used by Major McNee. A drop each of II and III serums are placed at opposite ends of a slide, and into these are stirred small quantities of blood picked up in the eye of the needle used for pricking the finger. After rocking gently, the slide is covered with a Record syringe box lid for four minutes, rocked again, allowed to stand another minute, and then read. After two demonstrations the dressers could do the test, and proceeded under supervision to test one another and their comrades. Stock serums were prepared from a clear-cut II and III by bleeding into a 2 oz. conical graduate, loosening the clot round the top one hour later with a probe, and next morning transferring the supernatant serum to boiled antitoxic serum bottles with an eye dropper and

adding one drop of 5 per cent. carbolic for every ten drops of serum. These bottles, together with two eye droppers marked II and III and a safety-pin box of slides, fitted easily into an ordinary oblong cigarette box. On the inside of the lid the following table was pasted:

	Red Blood Cells.	Red Blood Cells.	Red Blood Cells.	Red Blood Cells.	Frequency of Group.
	1	2	3	4.	Per cent.
Serum 1 ...	—	—	—	—	8
Serum 2 ...	+	—	+	—	40
Serum 3 ...	+	+	—	—	10
Serum 4 ...	+	+	+	—	42

+ = Agglutination. — = No agglutination.

The important point is the effect of the patient's plasma on the cells to be introduced.

This test case fitted readily into one of the spaces in the field medical pannier allotted to tubes of vaseline. With it a dresser could determine the blood group of a volunteer and a patient in a few minutes.

The Operation.

The syringe method with glass cannulae in the veins was used; needles were tried once, but the dresser assistant got his out of the vein and trouble resulted. Two inches of the thick-walled rubber tubing of the aspiration set were fitted to each cannula, one inch being free to receive the end of the syringe. Five per cent. carbolic was used for numbing and sterilizing the skin; the veins were dissected out and ligatures placed by the medical officer, and then he and the dresser together cut their respective veins and introduced the cannulae—that in the donor being directed distally. The cannulae were held in place and blocked by pinching the rubber tubing. The 20 c.cm. glass syringes, four in number, fitted snugly into the rubber connexions and were kept going in a cycle, being washed out each time in a vessel of boiled saline by a second dresser, and laid on a piece of sterile gauze ready for use. Plugging of the donor's cannula by the wall of the vein being drawn against its end may be overcome by stopping the suction on the syringe and sliding the cannula slightly in or out. The syringes and cannulae may be carried, sterile, in an old tablet tin (obtained from advanced dépôt medical stores) with the partitions removed.

Illustrative Cases.

CASE I.

Severe lacerated shell wound of the left thigh, and fracture of the femur, admitted to dressing station with tourniquet and Thomas splint applied. Intravenous injection of one pint 5 per cent. gum and 4 per cent. sodium bicarbonate* produced a slight improvement in the pulse. The blood was tested, and found to belong to Group IV. A robust infantryman, buried by shell, offered some blood, but turned out to belong to Group II, and had to be rejected. A slightly wounded corporal, Group IV, volunteered, and a pint of his blood was transfused without difficulty by the syringe method. Some improvement was noted, and the patient was warmed up and sent on. He died just before reaching the casualty clearing station. We have since thought that if this case had been given more blood, and allowed to warm up longer in the dressing station, he might have survived the long ambulance journey.

CASE II.

Shell wound of the thigh and fracture of the femur brought into dressing station with legs tied together and considerable blood in the stretcher; morphine gr. $\frac{1}{2}$ had already been given. A tourniquet was at once applied and 1 oz. 50 per cent. ether in liquid paraffin given between mouthfuls of port wine (Gwathmey's oral analgesia). He was allowed to warm up for fifteen minutes; meanwhile his blood was found to belong to Group II. A Thomas splint was then applied without pain, the wounds packed, the tourniquet removed, and one pint gum solution given intravenously; he was wrapped up and allowed to remain on a heated stretcher. In less than an hour he was found to be in shock—extremely pale with bloodless conjunctivae and lead-blue lips, barely conscious, but the radial pulse still faintly perceptible. A donor (Group IV) with a sprained ankle was found and 800 c.cm. blood transfused. After the operation the patient's neck and face were definitely red and his cheeks warm to the touch. His mental state improved immediately, and he raised his head and smiled and talked to the dressers. After drinking some tea and café-au-lait, resting meanwhile on a heated stretcher, he was sent on to a casualty clearing station surrounded with hot-water bottles, where he

* Since the publication of Professor Bayliss's article we have changed our gum formula to 6 per cent. gum and 0.9 per cent. sodium chloride.