In the case of circumscribed arterial haematoma accompanying a small wound of the limb, time alone can show if an attempt to suture the artery is good. One should most probably be guided by the state of the circulation in the distal portion of the limb.

(b)

In dealing with gas gangrene in a wounded segment of a limb and deciding on the advisability of amputation, it should be borne in mind that it is usually only the wounded muscles that become gaseous and that incision or ablation of such muscles is often sufficient to arrest the disease and stop the infection (see Case vi).

In the case of the thigh the ablation of muscles may present difficulties, but in the leg this part of the limb can often be saved by the ablation of the anterior tibial group, and the same applies to the muscles of the forearm. The brick-red colour and the non-contractility will show at once which muscles are past saving.

(c)

When gas gangrene occurs in a segment of a limb distal to the segment wounded it nearly always means that the main artery is blocked, and amputation of the gangrenous segment is the only course.

(d)

The presence of crepitation in tissues apart from other signs is of no special importance. A limb should not be sacrificed on account of crepitant skin (see Case ii). The state of the muscles and the number dead should be ascertained before amputation is performed, otherwise a limb or a very considerable portion of its length may be sacrificed unnecessarily.

The disease is the great bugbear of the surgeon at the front. It involves much labour and complicates the evacuation of the wounded. It occurs in all sorts of wounds, whether small or large, and with all sorts of projectiles. There is no wound, however insignificant, that one can feel happy about if not opened up. It is true that the disease is not so dangerous now as it used to be, because of the universal opening up of wounds, but the amount of trouble that it entails and the amount of disturbance that it is necessary to inflict on a grievously wounded patient makes one long for some remedy other than surgical interference.

THE DIRECT TRANSFUSION OF BLOOD:

*ITS VALUE IN HAEMORRHAGE AND SHOCK
IN THE TREATMENT OF THE
WOUNDED IN WAR.**

BY

A. PRIMROSE, M.B., C.M.EDIN., M.R.C.S.ENG.,
LIEUTENANT-COLONEL C.A.M.C.,

AND

E. S. RYERSON, M.B.TORONTO,
MAJOR C.A.M.C.

THE direct transfusion of human blood from one individual to another is an operation of great antiquity, but in the history of medicine it has never been as extensively employed as it is to-day. From time to time transfusion of blood has been abandoned, largely because of technical difficulties in its performance, but of late years, as the result of the introduction of more perfect and less complex methods, the operation has become much more generally employed. Its value as a therapeutic measure in the treatment of many pathological conditions has in recent years been established on a scientific basis. Thus it has proved of great service in the treatment of haemorrhage, shock, illuminating gas poisoning, and of more doubtful value in pernicious anaemia and certain toxæmias.

We will not review the observations which have been made in recent medical literature regarding the value of transfusion in the multitudinous conditions in which it has been used; we propose to restrict our observations to the value of direct transfusion of blood in the emergencies of military surgery. There may be some question as to its efficacy in many of the conditions in which it has been

employed, but in haemorrhage and shock, more particularly in shock accompanied by haemorrhage, its value has been proved beyond a shadow of doubt. We may assert that we have no more efficient means at our command to save life in cases of severe haemorrhage than by the direct transfusion of human blood from one individual to another. This has been proved not only in traumatic haemorrhage (primary and secondary), but in haemorrhage from such conditions as gastric ulcer, typhoid ulcer, ruptured extra-uterine pregnancy, the haemorrhages of the newborn, and in haemophilia.

If we inquire into facts which are known regarding the effect of introducing human blood into the vascular system of an individual suffering from haemorrhage, we realize the difficulty and complexity of the problem involved in our effort to appreciate the full result of transfusion. As regards the transfused blood, we have no precise knowledge concerning the fate of the corpuscular elements, nor of the plasma. The possibility of the harmful effect of lysins or agglutinins in the blood of the donor or recipient has been feared, but this has been greatly exaggerated. A large amount of clinical evidence has accumulated to warrant us in assuming that no serious harm is to be anticipated from such sources. The laboratory tests for haemolysis and agglutination may be carried out if time and facilities permit, but they are not necessary and are by no means trustworthy. The laboratory findings in haemolysis, for example, have been found at times at variance with the actual results obtained in the living body. No fatal result from either haemolysis or agglutination has hitherto been reported.

The danger of the transmission of disease makes it essential we should inquire into the past record of the donor, particularly as to whether or not he has had syphilis.

Two results of transfusion stand out prominently and are unquestionably of enormous value in the treatment of haemorrhage. These are, first, it increases the power of coagulation of the blood, and second, it improves the local resistance of the tissues to infection. These facts have been recorded by a number of observers over a large series of cases and have been shown in the most striking fashion in the cases of secondary haemorrhage which we have personally treated by transfusion. It we stopped there and claimed no more for transfusion our contention in urging its employment in such cases would be justified. There are, however, other effects which are more difficult to analyse, and yet which we are warranted in believing are of great service. If we introduce, say, a litre of blood with all its constituent elements into the vascular system of an individual suffering from the direct effects of a severe haemorrhage, and if we have reason to believe the transfused blood takes on its normal function in the recipient, the ideal therapeutic measure has obviously been employed. This is admittedly a very complex problem, and we acknowledge our ground is not as sure in the matter of conclusive evidence as it is regarding the effect upon the coagulability of the blood and the increased resistance to infection. If, however, we employ all known tests after transfusion and find no evidence of haemolysis, we have strong ground for assuming that the donor's blood, in all its elements, circulates and functions in the recipient. If, for example, we find no evidence of haemoglobin in the urine, we certainly have no lacking of the red cells in the circulating blood. The possibility of phagocytic destruction of red cells in the liver cannot so readily be disposed of, and we have no means of determining this factor. The blood count does not help us to any extent, because we find, for example, that if a litre of blood is transfused into a patient who is exsanguinated, the blood count is not necessarily altered in spite of the fact that the red cells are low in our patient at the time. Thus, recently a patient with a red count of 3,000,000 received a litre of blood from a donor with a red count of 5,000,000. Two hours subsequently the red cells in the recipient were still 3,000,000, but his colour was markedly improved and his blood pressure and pulse were maintained at normal. Obviously the introduction of the more concentrated blood resulted in an osmosis which quickly restored the former equilibrium and resulted in a dilution of the mixed blood now circulating. There was no evidence of haemolysis and the result of transfusion was to increase

* Read before the Salonica Medical Society, April 5th, 1916.

Chart indicating the rapidity of the pulse and the condition of the blood pressure before, during, and after the operation of transfusion in a man who was in a desperate condition from secondary haemorrhage. The details of the history of the case are recorded in the paper. Continuous line = blood pressure. Interrupted line = pulse rate. T.S. = beginning of transfusion. T.F. = end of transfusion.

probably by one-third or more the amount of blood circulating in his vascular system. The result was vast improvement in his general condition, with cessation of haemorrhage and rapid healing of his wound.

ILLUSTRATIVE CASES.

Cases illustrating the beneficial effect of the direct transfusion of human blood in haemorrhage have come under the observation of each of us. Unfortunately our clinical notes of cases occurring at home are not available for the record of complete details in this paper, but the main facts regarding two such may be cited. A lad, 16 years of age, had a deep cut, inflicted by an axe, in the calf of the leg. The wound suppurated and secondary haemorrhage from the posterior tibial artery occurred. He was sent to hospital and in the clinic the artery was tied high in the wound; haemorrhage recurring, the vessel was ligatured through a fresh incision at the lower end of the popliteal space. Subsequently the wound continued to suppurate, the pulse was rapid and thready, and he steadily lost ground. Direct transfusion of blood was undertaken; the lad's brother acted as donor and the operation was performed by means of Crile's cannulae, and a considerable amount of blood was transfused. Towards the end of the operation the lad spontaneously expressed himself as feeling better, his pulse was no longer rapid and the blood pressure improved. Subsequently the wound became healthy, no further haemorrhage occurred, and he made an uninterrupted recovery.

Another instance in the clinic of one of us was the case of a girl exsanguinated by repeated haemorrhages from a gastric ulcer. Her physician considered her condition most critical; she was blanched, with a rapid pulse, low blood pressure, and sighing respirations, with restlessness. After transfusion she immediately improved, and made an uninterrupted recovery, with no recurrence of haemorrhage. Several other instances might be quoted from our experience at home were our notes available. Two examples from our hospital in the field at Salonica may be noted in some detail.

CASE I.

A corporal, aged 42, admitted to No. 4 Canadian General Hospital on December 17th, 1915, had been knocked down by a motor lorry, the wheel passing over his left thigh and left arm. There was a compound comminuted fracture of the upper third of the femur, and a compound fracture of the humerus above the insertion of the deltoid muscle. In both arm and thigh torn muscle protruded from the wounds, which were of a "bursting" character, and in the thigh, on palpation, the muscles seemed to be extensively torn away from their pelvic attachments. He had lost a great deal of blood, and was in a condition of profound shock. The fractured limbs were secured on splints, with as efficient reduction as his condition would permit. It was impossible to administer a general anaesthetic. Morphine was administered to relieve his pain and combat shock. He rallied somewhat, but remained for some days in a critical state in spite of the administration of normal saline solution.

On Christmas day (one week after admission) his condition seemed desperate and it was determined to transfuse human blood. A donor was easily found and we transfused 815 c.cm. of blood. The patient expressed himself as feeling better; he said he felt "warm," his pallid lips became red, and his condition of utter exhaustion gave place to one of comparative comfort. The pulse became slow, regular, and full. During the

next few days improvement in his general condition was maintained. Unfortunately the record of the blood picture before transfusion has been mislaid, but subsequently the record is as follows:

- Dec. 26th. Haemoglobin, 36 per cent.; red blood cells, 3,050,000.
- Dec. 29th. Haemoglobin, 40 per cent.; red blood cells, 3,700,000.
- Jan. 20th. Haemoglobin, 41 per cent.; red blood cells, 3,660,000.
- Feb. 11th. Haemoglobin, 58 per cent.; red blood cells, 4,460,000.

The urine was tested for haemoglobin for a few days after the transfusion, with negative results.

This patient left hospital on a hospital ship in good condition; the fractures had united, but a sinus still persisted in the thigh.

CASE II.

A second case treated by transfusion in the Canadian Hospital at Salonica was one in which haemorrhage threatened to prove fatal. Pte. H., aged 47, had been operated upon by one of our colleagues for haemorrhoids. The operation performed was excision and ligature. On the third day after the operation a considerable haemorrhage took place; this recurred on the fourth day when, under a general anaesthetic, the area of operation was examined and some additional sutures inserted. The wound looked sloughy and unhealthy. Normal saline solution was administered and the general condition improved and bleeding ceased.

On the fifth day haemorrhage once more occurred, and the patient's case became critical. He was blanched, with rapid pulse, sighing respirations, and exhibited restlessness. It was determined to transfuse him without delay, and he was transferred to the operating tent for that purpose. The pulse was 150 and blood pressure 50. While waiting for the final preparation of instruments, etc., his condition became so bad that we feared he would die ere we started the operation. His pulse was hardly perceptible and very rapid. We transfused 1,000 c.cm. of blood, with excellent immediate results. The actual operation lasted thirty minutes, and when completed the patient had a pulse of 116 and a blood pressure of 96. The improvement was more than maintained. On the following day the pulse was 100 and the blood pressure 110.

The accompanying chart gives a detailed record of the pulse and blood pressure not only before and after, but during the process of transfusion. It will be seen that the response was immediate.

A point worthy of note in this case is that not only did haemorrhage not recur, but the wound subsequent to transfusion took on healthy action and healed readily. On the other hand, while on a previous occasion the patient showed an immediate beneficial response to the action of normal saline solution, then the haemorrhage recurred and the wound remained unhealthy.

Subsequent to the transfusion of human blood in these two cases we tested the urine but found no haemoglobin. In neither case did we find any appreciable immediate increase in the red cell count. In the first case the record has already been given. In the second case the red cells before transfusion were 3,000,000, with 50 per cent. haemoglobin, and three days subsequently the record was practically unaltered, as it was also three hours after the operation. In both cases a normal blood picture was, however, slowly attained.

These cases sufficiently illustrate the beneficial effect of the direct transfusion of human blood. It may be added that no harm resulted to the donors from the withdrawal of such seemingly large quantities of blood. They complained of little or no discomfort, and were able to return to duty after a brief interval.

METHOD.

The apparatus used is very simple. The accompanying diagram illustrates it sufficiently well. A glass cannula is introduced into the median basilic vein and is attached to a 20 c.cm. glass syringe by an intervening piece of rubber tubing. One glass cannula is placed in the proximal end of the vein of the recipient and another in the distal end of that of the donor. There should be at hand, if possible, ten syringes. These are all sterilized by heat and are all coated internally with liquid paraffin. This is accomplished by first dipping the plunger of the syringe in the paraffin and then, after attaching the tube and cannula, the paraffin is drawn up

Diagram illustrating the apparatus for transfusion and the method of its employment as described in the text.

through the whole apparatus and expelled. An essential part of the procedure is to prevent any stagnation in the flow through the cannula during the operation. This is accomplished by using normal saline solution as a substitute for blood where a syringe of blood is not available. Thus, for some reason the assistant who is drawing off blood from the donor may encounter some momentary cause of delay; under such conditions the surgeon takes a syringe of normal saline solution, and by slowly pressing the piston of the syringe, keeps a current of fluid moving in the cannula of the recipient until such time as the syringe of blood is available.

The uncoupling of the syringe is always made at its junction with the rubber tubing; pressure on the tubing between thumb and finger is sufficient to control the flow during the process.

A current of blood or normal saline solution is constantly kept up. The amount of normal saline solution thus introduced is negligible, as it is introduced very slowly. Conditions may arise where there is some delay which necessitates the similar use of normal saline solution in the case of the donor. Here, too, the current of flow must be constant. Another point of some importance which one learns by experience is that after about 500 c.cm. have been transfused it is advisable to employ syringes newly coated with paraffin, otherwise there is a tendency to clot. The operation may be carried out very rapidly and, in our experience, without difficulty. One great advantage over any method in which the donor and recipient are buckled together by cannulae is that both individuals are free to move about, and are able to alter their position, or take a drink, etc., without interfering with the operation. Those who have tried both methods will realize the tremendous advantage in this, particularly if the recipient is very ill.

The apparatus we have described is not new. The principle of the syringe and cannula method was first brought to our attention by Captain L. Bruce Robertson, one of our colleagues in Toronto at the Hospital for Sick Children there. He had employed it in a considerable number of instances with most gratifying results in such cases as "haemorrhage in the newly-born," and in haemophilia. Captain Robertson in turn obtained the idea from one of the New York clinics. Unfortunately we are unable to obtain the literature which would enable us to place the credit where it is due.

ITS VALUE IN MILITARY SURGERY.

The advantage of the direct transfusion of human blood in the cases of severe haemorrhage which we encounter in the emergencies of military surgery cannot, to our minds,

be overestimated. In cases of secondary haemorrhage with sloughy wounds it is the ideal treatment, and has great advantages over normal saline solution. We know that the latter diminishes the coagulability of the blood while the former increases it. Further, the transfusion of human blood acts locally upon the wound, and induces healthy reaction there. Lastly, we have reason to believe that all the elements of transfused blood function in the recipient. If such be the case it is undoubtedly the ideal therapeutic measure in haemorrhage, and in cases where there is shock *plus* haemorrhage.

Recent articles show that haemorrhage is one of the main causes of the fatal issue in bullet wounds of the abdomen—most writers indeed placing it as the chief cause of death. If such cases live long enough to reach the operating table their chances of recovery would undoubtedly be vastly improved if transfusion of human blood were undertaken either while the operative procedure were in progress or immediately afterwards. The symptoms due to haemorrhage and shock will be lessened and immediate beneficial results will be obtained.

Our former colleague, Captain L. Bruce Robertson, has successfully demonstrated the value of the treatment in Northern France, where he has employed it in No. 2 Canadian Casualty Clearing Hospital. Unfortunately we cannot give details of his cases, but in private correspondence he asserts that the results obtained have been most gratifying. The apparatus is simple and could well be employed in hospital units near the front. Captain Robertson was prepared to carry it out in a field ambulance unit if necessary.

NOTE.—Since preparing this paper for the press we learn that Captain Robertson has published the details of seven cases successfully treated in France, in an article entitled "The Transfusion of Whole Blood: a Suggestion for its more Frequent Employment in War Surgery," in the BRITISH MEDICAL JOURNAL for July 8th, p. 38.

TRENCH FEVER: THE FIELD VOLE A POSSIBLE ORIGIN.

BY

W. J. RUTHERFURD, M.D., CH.B. GLASG.,
TEMPORARY LIEUTENANT, R.A.M.C.

VARIOUS more or less unsatisfactory suggestions have been put forward in explanation of the occurrence of "trench fever" among the troops in the western front. It is the object of this note to suggest still another tentative theory as to the mode of origin of this quite definite condition.

It is now well known that a new disease, to which this name has been applied in default of a better, has appeared among the soldiers in the trenches, and also to a very much lesser extent among the medical personnel of the field ambulances through which the sick are evacuated. New troops occupying an old line of trenches remain healthy for the first four or five days or so, and it is only towards the end of that time—so far as my experience goes—that cases begin to turn up suffering from a fever which, as the experience of the regimental medical officer increases, can be recognized as being of this nature without delaying diagnosis until the temperature curve has been followed over a considerable period.

The question naturally presents itself when a new disease is encountered, Is there any other new condition or association of conditions existing with regard to those attacked by this disease, and, if so, is it possible to correlate it with the presence of the disorder in question? Looked at in this way, it is not difficult to assert that there is such a new condition of biological importance, this being the commensal association (if the term be permissible) with human beings of the long-tailed field vole, or field mouse, as it is commonly called.

The trenches along the western front have for some considerable time swarmed with rats and mice; they haunt the shelters with incredible boldness, while by night they scuffle and squeak in the roofs of the dug-outs, and run freely along the top of the trenches. Rats, as is common knowledge, are the disseminators of plague as well as of the less familiar sokodu, or rat-bite fever (so-called), besides being subject to the bacillus of pseudo-leprosy and acting as the source of trichiniasis by conveying