*INTRODUCTORY NOTES*

*The article reproduced below is from the US Army Medical Department titled 'Transfusion before World War 1 – Office of Medical History – Army' and is the first of a series of 20 chapters under the main title of 'Blood Program in World War II' by Brigadier General Douglas B. Kendrick, MC, USA. It is presented in this format, together with the original illustrations, as an additional source of information relating to the history of blood transfusion.*

*The original article can be accessed using the URL:*
*http://history.amedd.army.mil/booksdocs/wwii/blood/chapter1.htm*
*Accessed: 07-07-2020*

*The article opens with an historical introduction describing the early days of blood transfusion which concentrates on the difficulties caused by coagulation, incompatibility and equipment. This is followed by a section on blood transfusion in WW1 that provides both British and US information relating to the techniques used and the difficulties relating to blood grouping as well as identifying the indications for the transfusion of battle casualties. This section also provides information on the types and use of replacement fluids as well as their post-war evaluation. The section on the Spanish Civil War includes valuable information regarding the Barcelona Blood Transfusion Service and the Madrid Blood Transfusion Institute. The article then provides information regarding the organisation and functions of the 'Blood for Britain' programme as well as the British, Soviet and German blood programmes in WW2.*

## CHAPTER 1: HISTORICAL NOTE

### TRANSFUSION BEFORE WORLD WAR I

#### Historical Note

Although the concept of the therapeutic value of blood dates back to antiquity, transfusion in the modern sense of the term was a practical impossibility until William Harvey, in 1616, announced his discovery of the circulation of the blood.[1] This discovery opened the way for serious experiments on the infusion of various substances into the bloodstream and eventually led to the use of whole blood for transfusion.

[1] The following brief historical account of the development of blood transfusion is necessary for an understanding of the medico-military employment of this measure, a use not suggested up to World War I. The material included, unless otherwise indicated, is derived from (1) the detailed historical account in Kilduffe and DeBakey's "The Blood Bank and the Technique and Therapeutics of Transfusions" *(1),* which has an appended list of 207 (183 numbered) references, and (2) Lewisohn's *(2, 3)* and Ottenberg's *(4)* accounts of the contributions of Mount Sinai Hospital in New York to this therapeutic technique.

Claims to priority are various and confusing. It is clear, however, that Richard Lower, inspired by the previous experiments of Sir Christopher Wren in infusion techniques, performed the first successful animal transfusion in 1665, when he transferred blood from the carotid artery of one dog to the jugular vein of another. In November 1667, Lower transfused Mr. Arthur Coga, "a mildly melancholy insane man," with the blood

of a lamb. Mr. Coga, according to Pepys, described his experience in Latin before the Royal Society of Medicine and stated that he was much better. He impressed Pepys as "cracked a little in his head."

The next animal-to-human transfusions were also performed on generally the same indications, by Jean Baptiste Denis, physician to Louis XIV. When Denis' fourth attempt ended fatally, he was charged with murder. He was eventually exonerated, but, 10 years later, the procedure was prohibited by law in France as well as in Italy and was also forbidden by the Royal Society of Medicine in England.

For the next 150 years, there was little interest in transfusion, but it is significant that Nuck in 1714 and Cantwell in 1749 declared that this procedure would be of value in severe haemorrhage. When interest in transfusion was revived by James Blundell *(5-7)* in 1818, it was on the basis of replacement of lost blood in puerperal haemorrhage and after a series of experiments in which he had demonstrated that human blood loses none of its "vital properties" by passage through transfusion equipment (figs. 1 and 2). Blundell failed in his first four desperate attempts to save women on the point of death from postpartum haemorrhage, but he succeeded in five of the next six attempts.

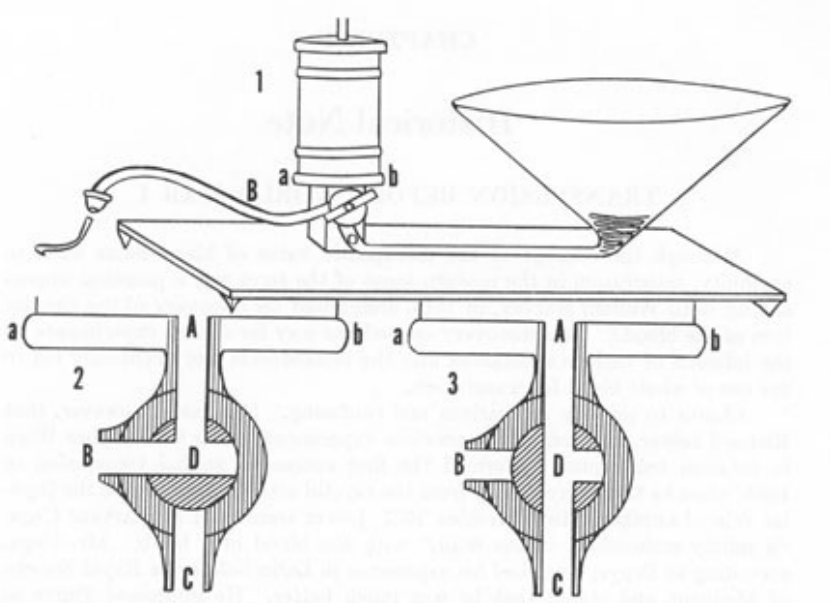


FIGURE 1.—Apparatus used by Blundell for experimental blood transfusion, 1818. 1 (Blundell's original numbers and letters are retained). Syringe, etc. 2, 3. Structure of double-way cock. A*ab*. Head of syringe. ADB (fig. 2). Channel by which blood is expelled while ADC is closed. ADC (fig. 3). Channel by which blood enters while ADB is closed. Change is effected by giving plug D a quarter-turn (*2*).

In 1859, in reporting a successful transfusion, Benedict *(8)* laid down the conditions under which this operation should be practiced. He considered it applicable to no pathologic state save that …which is commonly called 'collapse,' induced by haemorrhage, by certain exhausting discharges, or by utter inability to receive or retain nutriment; and the only transfusion now sanctioned, either by physiology or by common sense, is that of *human venous blood into human veins, identical, as nearly as* possible, with that which has been lost, and in quantity just sufficient to arrest the tendency toward death.

Benedict *(9)* could find only 21 cases recorded up to 1853 in which transfusions had been "practiced under these conditions." There were 19 survivals in the 21 cases.

In 1875, Landois *(10),* in a comprehensive monograph on transfusion, collected 347 cases in which human blood had been used and 129 cases in which animal blood had been used. By this time, important studies on the physiology of the blood were being performed by a number of qualified observers, and some physicians, such as Fordyce Barker, advocated transfusion "… not exclusively in those desperate cases where favourable results are hardly looked for but …before patients have arrived at, and fallen into, this desperate condition."

Techniques in use included transfusion with defibrinated blood, mediate transfusion with pure blood, immediate transfusion from vein to vein, and immediate transfusion from artery to vein.

FIGURE 2.—Clinical transfusion with Blundell gravitator for transmitting "blood in a regulated stream from one individual to another"(*3*).

Although the indications and rationale of blood transfusion were by this time apparently quite well understood, the indications during the last quarter of the century again became vague and irrational, the procedure was employed indiscriminately, and the number of severe reactions and fatalities increased. As a result, transfusion again began to be considered as a hazardous, and even a disreputable, procedure, to be employed only as a last resort and in desperation.

**Special Problems**

During the first years of the 20th century, a blood transfusion was frequently a more difficult technical procedure, and sometimes a procedure fraught with greater risks, than a major operation. Its development as an effective and safe therapeutic method required the solution of a number of special problems:

1. *Blood coagulation.* First efforts to overcome this difficulty were made in 1835, with the use of defibrinated blood by Bischoff, and terminated in 1914, with the successful use of sodium citrate by Hustin, Weil, and Lewisohn *(2, 3)* (p. 218).

2. *Agglutination and haemolysis from admixture of incompatible bloods.* The way was opened to the solution of this special problem in 1900, when Landsteiner *(11)* published his epochal work on the identification of blood groups, based on his previous demonstration of the presence of isoagglutinating and isoagglutinable substances in the blood. Jansky in 1907 and Moss 3 years later, without knowledge

of Jansky's studies, worked out the reciprocal agglutinating reactions of the four blood groups and classified them accordingly. The confusion that arose because of differences in nomenclature was eliminated after World War I, when the numbers previously used to designate blood groups were replaced by the letters A, B, AB, and O, each group thus being designated by the agglutinogens in Landsteiner's original scheme.

Communications in the early years of the 20th century were often slow, and foreign medical literature had only a limited circulation in the United States. No practical use, therefore, was made of Landsteiner's work until 1907, when Ottenberg *(4)*, at Mount Sinai Hospital in New York, first matched donor and recipient before giving blood and thus made transfusion a safe procedure from the standpoint of compatibility. The validity of Ottenberg's work was not immediately realized; his offer to perform compatibility tests for the surgeons at his own hospital had no general acceptance for almost 5 years because such tests were considered unnecessary or misleading.

In 1911, Ottenberg demonstrated that it was safe to use as a donor a person whose serum agglutinated the recipient's red cells but unsafe and dangerous to use one whose red cells were acted upon by the recipient's serum. This demonstration eventually led to the widespread employment of group O donors as universal donors, since the red blood cells of this blood group are not agglutinable by the serum of any other blood group.

3. *Technical difficulties.* Until 1913, direct transfusion was used to the exclusion of any other technique. This was a difficult and time-consuming method, requiring a specially trained team to carry it out and totally unsuited for use in sudden emergencies. In 1892, von Ziemssen of Munich had performed transfusion by the syringe technique, but his report attracted no attention and when Lindeman *(12)* described it in 1913, it was, for all practical purposes, a new method. With this technique, no dissection of blood vessels was necessary in either donor or recipient, and the exact quantity of blood transfused was known. The technique, however, required a trained team of at least four persons and the use of a large number of expensive syringes. Also, rapid injection of the blood was mandatory. In 1915, Unger *(13)* introduced an apparatus based on the principle of the two-way stopcock, which overcame many of these difficulties. Dozens of variations of this apparatus were introduced during the next 15 years.

4. *Infection.* Infection ceased to be a major problem after first antiseptic, and then aseptic, techniques came into general use and as long as transfusion was employed only in hospitals and on what amounted to elective indications. The open containers originally used to collect blood for indirect transfusion first became impractical, and then a real source of danger, when indications for transfusion were extended.

## BLOOD TRANSFUSION IN WORLD WAR I

### The British Experience

In June of 1918, an editorial writer in the *Lancet* doubted that as recently as 4 years earlier any surgeon could have been found to perform "the operation" of transfusion in England *(14).* In the next issue, Sir Berkeley Moynihan *(15)* took exception to that statement: He and his associates in Leeds had been performing transfusion regularly for 10 years, first by the direct, and later by the indirect, technique.

The editorial writer's statement was, however, generally true. Blood transfusion was not practiced by the majority of surgeons in Great Britain before World War I, and its use in the last 2 years of the war was chiefly derived from the work which had been done on it in the United States.

**Techniques**

Direct transfusion, as might have been expected, proved a completely impractical method in military surgery. The elaborate preparation required in the Kimpton-Brown technique makes one wonder how it could have been employed at all in a busy casualty clearing station, but Fullerton and his associates *(16),* using improvised equipment, employed the method in 19 casualties at the Boulogne base in 1916. The 15 deaths were not too discouraging, since the blood was given only to patients whose condition was considered desperate. In 1917, U.S. Army medical officers introduced the standard Kimpton-Brown equipment into British hospitals, and numerous patients were treated by this technique in casualty clearing stations of the British Second Army.

In a series of reports between 1916 and 1918, Bruce Robertson *(17-20),* of the Canadian Army, explained the advantages of the syringe-cannula technique, which he had introduced into the British Second Army area. The method was far simpler than the Kimpton-Brown technique, but at that it was not simple, and it required a team of three persons to carry it out.

The use of preserved blood was introduced into a casualty clearing station in the British Third Army during the battle of Cambrai in November 1917 by Capt. (later Maj.) Oswald H. Robertson, MORC, USA *(21, 22).* His reasoning was that if blood had to be collected as casualties arrived, the number of transfusions given would necessarily be limited. The solution seemed to him to be the use of human red blood cells collected and stored in advance of the need.

Only group O (then termed group IV) blood was used. The 500 cc. taken from each donor was collected in the Rous-Turner glucose-citrate solution (p. 217) and stored in an icebox. After the blood had settled for 4 or 5 days, the cell suspension contained no more citrate than would be used in ordinary citrated transfusions. The majority of transfusions were given within 10 to 14 days after the blood had been collected, but in some instances they were given with 26-day-old blood. The length of time the blood was kept did not seem to influence the results. The blood arrived in good condition, with no evidence of haemolysis, after transportation by ambulance for 6 to 8 miles over rough roads, a demonstration later repeated by Capt. Kenneth Walker, who carried a bottle of preserved blood with him during a journey from Arras to London. The 22 transfusions with preserved blood reported by Robertson in June 1918 were carried out on 20 patients, of whom 9 died but all of whom, it was thought, would have died unless they had received blood.

In 1918, transfusions were carried out farther forward than casualty clearing stations, chiefly due to the efforts of Captain Walker, Capt. Norman M. Guiou *(23)* of the Canadian Army, and Major Holmes-à-Court of the Australian Army *(22).* The syringe technique, Guiou claimed, could "easily" be applied in advanced dressing stations and in the average regimental aid post. If casualties were given blood in these areas, he continued, they would be kept alive until they reached the casualty clearing station, where they could be treated surgically.

The official history of the British Medical Service in World War I concluded that whatever the merits of the various techniques of transfusion in civil life, there was no doubt of the superiority of the citrate method in wartime. It could be employed in

circumstances in which other methods were impractical. It was simpler than other methods. It permitted the transportation of blood from donor to recipient without interrupting an operation and further congesting an already overcrowded operating tent. A skilled "transfuser," devoting himself entirely to the task of drawing and citrating blood, could supply a dozen patients in need of blood, leaving to anaesthetists the "simple task" of administering the blood *(22)*.

**Donors**
There was no difficulty in procuring blood donors. Up to the middle of 1918, the spirit of comradeship was sufficient to supply them. Later, a 3-week leave in England after the donation secured many offers from lightly wounded men. Dental patients and soldiers with minor injuries, sprains, and flat feet were also used as donors. Syphilitic and malarial subjects were rejected, as well as those with other infectious diseases, such as trench fever. A healthy donor, it was thought, could withstand the loss of 700-1,000 cc. of blood.

**Blood grouping**
Early in the war, the precaution of blood grouping before transfusion was frequently omitted because it was impractical. A number of reactions were attributed to this omission, and by June 1918, Bruce Robertson *(19)* had observed three cases of fatal haemoglobinuria in 100 transfusions. Later in the war, preliminary blood grouping became the rule, but, when there were no facilities for laboratory work, his suggestion of a test injection was generally used, particularly in emergencies. If no symptoms occurred within 1 or 2 minutes after the injection of 15 to 20 cc. of donor blood, it was thought safe to proceed with the transfusion.

In November 1917, Maj. Roger I. Lee, MC, USA, writing in the *British Medical Journal (24),* described what he termed the "minimum procedure" to assure that the recipient's serum did not agglutinate the donor's cells. This extremely simple test continued to be useful until avid grouping serum became available after the war.[2]

[2] The use of plasma in place of blood was suggested by Gordon R. Ward *(25),* in March 1918, to avoid the risk of haemolysis of the recipient's plasma by the donor's corpuscles, but the suggestion was not acted upon in combat areas during the remainder of the First World War. In November 1918, however, Lt. Frank W. Hartman, MC, USN, used liquid plasma which he had prepared at the U.S. Naval Medical School for patients with severe influenza *(26).*

**Indications**
Indications for transfusion in the British Expeditionary Force included:

1. Preoperative preparation in severe haemorrhage and shock, in which blood replacement was considered the proper treatment for loss of blood. The time of the transfusion officer was not properly spent on casualties who were moribund. Although there was considerable argument about the relative effects of gum acacia and blood in shock, the most experienced surgeons considered transfusion far more efficacious. Captain Walker found that 70 percent of the casualties resuscitated by gum acacia infusions in field ambulances required blood when they reached the casualty clearing station. In rush periods, when time could not be taken, or facilities were not available, the need for transfusion was determined by the casualty's general appearance, pulse, and blood pressure. In severe haemorrhage, large amounts of blood (900 to 1,000 cc.) were recommended; 500 to 600 cc. was considered adequate in shock.[3]

[3] The World War II concept of haemorrhage as the cause of shock in military injuries was not one of the theories advanced to explain shock in World War I (p. 37).

2. During operation

3. After operation, after a delay to determine whether the depression might be due to the anaesthetic, especially if an anaesthetic other than gas-oxygen had been used.

4. Carbon monoxide poisoning.

5. Septicemia and chronic wound infection.

Bruce Robertson *(20)* emphasized the importance of the timing of transfusion. It was a temptation, he said, to use other measures first, but clinical observation showed that transfusion was not so effective after the "exsanguinated condition" had persisted for several hours and degenerative changes had occurred in the organism. Properly timed transfusions could revive inoperable patients and bad-risk patients to a degree that permitted radical surgery, with a good chance of recovery. Gordon Watson, in a note attached to one of Robertson's papers *(20),* stated that there was no comparison between the results of transfusion, which were instantaneous and permanent, and those secured by infusions of saline, which were "a flash in the pan" and followed by more serious collapse.

**Transfusion program**

To resuscitation teams (a nomenclature later employed in World War II) was delegated the task of collaborating with surgeons at casualty clearing stations by relieving them of the special measures necessary in poor-risk casualties both before and after operation. Teams of sisters and orderlies experienced in this work were developed and proved very useful.

A formal transfusion program was instituted in the British Third Army as experience showed that transfusion forward of casualty clearing stations could save many lives *(22).* A centre was set up in connection with a group of casualty clearing stations, and instruction in transfusion techniques was given in it to field ambulance and regimental medical officers. When they had completed their courses, they were provided with the necessary equipment, and several divisions thus had one or more officers especially skilled in the treatment of severely wounded casualties.

The officer in charge of this centre, in addition to his teaching duties, made a point of being present during any large trench raid in the army area, so that transfusions could be given as indicated in aid posts or advanced dressing stations. Whatever the clinical results achieved - and many lives were undoubtedly saved by these arrangements - the morale effect of his presence on the men going over the top was so good that the combatant services soon got into the way of sending back word of impending raids to the shock centre. When several battalions were to participate in the operation, it was possible, with such advance notice, to select a central site to which badly wounded men could be sent from various aid posts for resuscitation and transfusion. It was also possible, with advance notice of military actions, to prepare a store of preserved blood at the centre to supply the needs of forward areas. When the blood was supplied, even a poorly equipped aid post could be used for transfusions.

## The United States Experience

### Replacement fluids

By the time the United States entered World War I, it was realized that the injection of physiologic salt solution or Ringer's solution was only temporarily effective in shock and haemorrhage and that the "internal transfusion" accomplished by hypertonic salt solution, which withdrew fluid from the tissues and thus increased the blood volume, was equally ineffective *(27)*. It had been concluded from Bayliss' studies that gum acacia was capable of replacing blood plasma and that it had a number of desirable properties (p. 384). There was considerably less agreement, however, about its clinical value. Maj. O. H. Robertson's survey of forward hospitals in October 1918 showed that some resuscitation teams praised it, some were indifferent to it, and some condemned it. The poorest results with it were reported in very severe haemorrhage and in shock that had been untreated for 15 to 20 hours.

Maj. W. Richard Ohler, MC *(28),* who had had an extensive wartime experience as a resuscitation officer, made the unqualified statement after the war that haemorrhage is the most important single factor in shock and that the amount of haemorrhage determines the degree of shock. When, therefore, the need is for oxygen-carrying corpuscles, no other intravenous solution will serve the purpose. When the United States entered World War I, physicians with the most experience in trauma took the position that when haemorrhage played a large role in the production of a circulatory deficiency, blood was preferable to any "indifferent" fluid. It was not until March 1918, however, that a committee representing the laboratory and surgical services of the U.S. Army Medical Department officially adopted transfusion with citrated blood as the method for combating shock and haemorrhage in hospitals of the American Expeditionary Forces.

### Donors

Hospital personnel were classified in blood groups for emergency use, but donors were chiefly secured from lightly wounded and gassed patients who, on admission, were sent to wards near the shock wards. Patients with scabies and convalescents who were non-febrile and in good condition also served as donors. No rewards were offered and all donations were voluntary, without compulsion of any kind. Not more than 600 cc. was drawn at any one time, and the same donor could not be used twice within one week.

### Technique

Equipment for blood transfusion (fig. 3) consisted of a l,000-cc. bottle with two rubber stoppers, each with two perforations; appropriate glass and rubber tubing; and two transfusion needles, a larger one for bleeding the donor and a smaller one for giving blood to the recipient. A satisfactory suction and pressure pump could be made front an ordinary Davidson syringe; suction or pressure was created as necessary by reversing the ends. The equipment was either sterilized in the autoclave or boiled in distilled or previously boiled water. The needles were sterilized just before they were needed, in boiling liquid petrolatum or Albolene, and were left in the medium until used. Great care was taken in cleansing the apparatus after the transfusion.

The blood was drawn into a solution of 0.6-percent sodium citrate in 700 cc. of physiologic salt solution. It was ordinarily used as soon as it was collected, but it could be kept for several hours. The container was kept in water at about body temperature during the transfusion. No provisions were made for transfusion during operation, but precautions were taken to lose as little blood as possible.

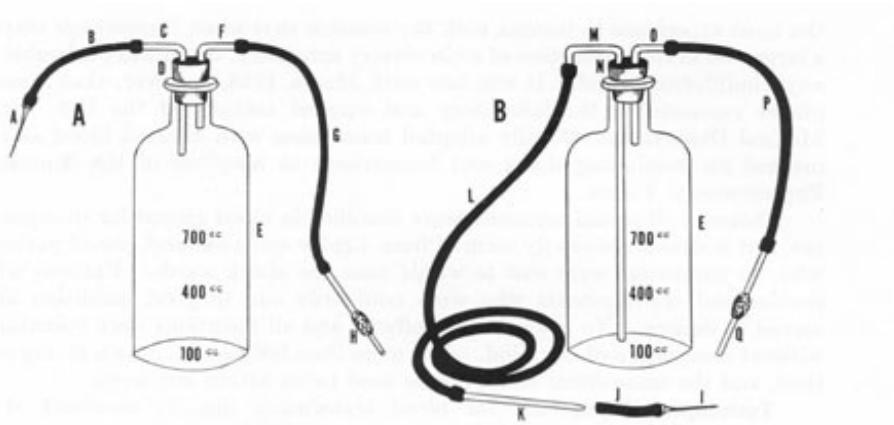


FIGURE 3.—Blood transfusion apparatus used in World War I.

A. a. Transfusion needle.
b. Rubber tube.
c. Glass tube.
d. Rubber stopper.
e. 1-liter bottle.
f. Glass tube.
g. Rubber tube.
h. Glass tube for suction, with cotton in bulb.

B. i. Transfusion needle.
j. Rubber tube.
k. Glass tube.
l. Rubber tube.
m. Glass tube.
n. Rubber stopper.
o. Glass tube.
p. Rubber tube.
q. Glass tube for exerting compression (cotton in bulb) (*27*).

**Post-war evaluation of replacement therapy**

A questionnaire circulated in advance of the 11th session of the Research Society of the American Red Cross in France, held on 22-23 November 1918 and attended by representatives of the Medical Departments of the Allied and U.S. Armies, produced the following information on replacement therapy (not all officers queried replied to all questions) *(29)*:

1. All 31 officers who voted on this question preferred blood to gum acacia-salt or salt solution.
2. No serum reactions were reported by 29 officers when blood was properly grouped. Five others reported slight or rare reactions.
3. Difficulties in transfusion therapy included the length of time necessary to collect the blood, clotting in the needle during administration of the blood, inability to secure donors; keeping donors under careful control, and the inconvenience of having corpsmen who served as donors off full duty for 24 to 48 hours after their donations.
4. Seven hospitals had no experience with blood transfusion in prolonged infections; 43 reported definite improvement after its use, 2 temporary improvement, and 10 no improvement.
5. Twenty-six medical officers preferred the sodium citrate technique of blood transfusion. Three preferred the paraffin-tube technique, and the Kimpton-Brown and the syringe techniques received one vote each.
6. Because of numerous unfavourable reactions and some deaths after its use, one hospital was "very positive against" gum acacia-salt solution, and others considered it very dangerous or found nothing to recommend it.

## SPANISH CIVIL WAR (1936-39)

### Barcelona Blood Transfusion Service

The Spanish Civil War *(30-31),* which ended in January 1939, almost 3 years before the United States entered World War II, proved conclusively, and for the first time in military history, the practicability of supplying wounded men in forward medical installations with stored blood secured from a civilian population. Franco's armies, following the practice of the German Army (p. 22), supplied blood at fully equipped medical centres in the rear. The Republic Army Medical Corps supplied it at advanced medical units in the field.

In the 2½ years of its operation, from August 1936 through January 1939, the Barcelona Blood Transfusion Service collected more than 9,000 litres of blood in 20,000 bleedings, prepared more than 27,000 tubes of blood for forward use, maintained a list of 28,900 donors, and also prepared all necessary grouping sera.

Blood was kept under refrigeration, which was provided by electric ice-boxes whenever current was available. It was supplied to classification stations in heat-insulated wood or canvas boxes, with thick cord linings.

Transfusion data were recorded on special cards provided with all blood containers. The records were so complete that it was possible to trace every container to its point of origin in the collection centre and to identify every forward hospital in which blood had been given, the data including the name of the person who had performed the transfusion. Blood was prescribed by surgeons but administered by personnel of specially trained transfusion teams.

Donors were between 18 and 50 years of age. All blood was collected into a closed system, under strictly aseptic precautions. Citrate and glucose were added after collection, and bloods of the same group were mixed.

### Clinical considerations

Only badly shocked casualties received blood at classification posts. Most transfusions were given in No. 1 hospitals, where very few seriously wounded patients did not receive them. Occasionally, if stored blood was not available or if the sector was particularly quiet, direct transfusions were given. The members of the hospital staff had previously been grouped and serologically tested against such emergencies.

Indications for blood and plasma administration were as follows:

1. Casualties with serious haemorrhage were given only blood, which was injected as rapidly as possible, because cardiac function soon deteriorates when systoles contract on a vacuum.
2. Casualties suffering from primary shock and haemorrhage were given both blood and plasma. If improvement followed the use of 2 pints of blood, a pint of plasma was given to "stabilize the improvement." Thereafter only plasma was used. If the response to the first transfusion was not satisfactory, a third pint of blood was given before plasma was used.
3. Casualties suffering only from shock were given 2 pints of plasma as quickly as possible, followed, if there was no improvement, by a pint of blood, also given quickly. If there was still no improvement, another pint of plasma and another pint of blood were given over the course of an hour.[4]

[4] The persisting distinction between shock and haemorrhage should be noted (p. 31).

The concept of blood replacement was that in "posthemorrhagic" shock, at least 40 percent of the lost fluid must be restored promptly. There were, however, no quick or reliable methods for estimating the amount of blood loss. Generally speaking, 500 cc. of blood or blood derivatives was required for each fall of 10 to 20 mm. Hg in the blood pressure. Failure of the transfusion to raise the blood pressure was assumed to mean continued bleeding and indicated the need for control of haemorrhage as well as additional transfusion.

Quick administration of blood and plasma was regarded as desirable and without risk of cardiac embarrassment, since most casualties were young and healthy. The rate of administration could be regulated from a slow drip up to 100 cc. per minute. Although most casualties received the first pint of blood more quickly than the remainder, no instance of dilatation of the right heart was recorded. As Whitby pointed out in 1945, failure to restore the blood volume was a greater risk than overloading the circulation *(32).* In less urgent cases, speed of transfusion was not so important as administration of the necessary amounts of blood. The amounts given before and after operation varied with individual needs. Trueta usually gave from 1,000 to 1,500 cc. per casualty. Patients with infected wounds required several transfusions to restore the haemoglobin to normal values.

**Madrid Blood Transfusion Institute**

In September 1937, Saxton *(33),* a member of the British Ambulance Unit in Spain, reported on the Madrid Blood Transfusion Institute, organized by the Sanidad Militar of the Spanish Republic, which was then supplying about 400 litres of preserved blood per month and whose output was steadily increasing. The full-time personnel consisted of five physicians; five nurses; five members of the secretariat, including interpreters; and a domestic staff.

For practical reasons, only donors of groups II and IV (Moss) were utilized. The donors, all volunteers, were between 18 and 50 years of age. They were given cards that permitted them to buy extra food and were sometimes also given small quantities of rice, condensed milk, or other staples at the time of the donation. They were liable to call not oftener than every 3 weeks, and they usually gave 500 cc. at a time. Blood storage was limited to 3 weeks.

Saxton's suggestion that the Sanidad Militar organize a large-scale supply of cadaver blood by the technique of Yudin (p. 24) does not seem to have been acted upon.

## BLOOD FOR BRITAIN

**Origin of Program**

The project in New York City hospitals which came to be known as Blood for Britain *(34, 35)* originated in June 1940, when Dr. Alexis Carrel, who had recently returned from France, made known the great need there for plasma for the treatment of shock in battle casualties. The idea of shipping plasma to France and England was suggested to the president of the Blood Transfusion Association of New York, and a meeting to discuss the possibility was called for 12 June 1940. It was attended by the trustees of the association; its Board of Medical Control; Dr. Carrel; experts in the field representing the Army, the Navy, NRC (National Research Council), and Rockefeller Institute; and representatives of a number of large pharmaceutical and biological firms.

It was the sense of the meeting that, even though the use of plasma was still in an experimental stage, enough knowledge was available to justify an effort at quantity production. The cooperation of the New York chapter of the American Red Cross was secured as soon as it was pointed out to its officials that the experience to be gained from this project would be of great assistance in the National Defence Program, one phase of which was the supply of plasma for the Armed Forces. At the suggestion of Col. (later Brig. Gen.) Charles C. Hillman, MC, Chief, Professional Services, Office of The Surgeon General, Army, close cooperation was established with the Subcommittee on Blood Substitutes, NRC, which had just been appointed (p. 74) and by whose advice the Army Medical Department was being guided in replacement therapy.

The program became operational on 15 August 1940, at the Presbyterian Hospital in New York, and terminated on 17 January 1941. All the plasma collected went to Great Britain, France having fallen shortly after the 12 June meeting. The program, which represented the first effort in the United States to collect large amounts of blood from voluntary civilian donors for military use, had great popular appeal, and during its existence, 14,556 donations were made.

**Technique of Collection and Shipment**

Liquid plasma was selected for processing rather than dried plasma, partly because the time element was vital and partly because of the expense of installing drying equipment, whose performance at this time was still inadequate and far from satisfactory.

Originally, the system by which the blood was collected was not completely closed. Later, it was realized that a completely closed system was imperative.

The plasma was separated by either sedimentation or centrifugation. To reduce viscosity, it was diluted with equal amounts of sterile physiologic salt solution; the solution, under 13 inches of water vacuum, was in the Baxter bottle (Plasmavac) in which it was finally dispensed. Merthiolate was added in quantity sufficient to guarantee dilution of 1:10,000 in the final plasma-saline mixture.

The finished product was shipped in 1,000-cc. bottles, six to a carton. Larger packages were not practical because the shipments were made by Clipper planes-this was long before the existence of a transatlantic airlift.

**Laboratory Tests and Losses from Contamination**

Exacting bacteriologic and toxicity controls were required before any lot of plasma was dispensed. These tests were carried out not only in the laboratories of the participating hospitals but also in a central laboratory, under the direction of Dr. Frank L. Meleney. When the material reached England, samples from each carton were also checked bacteriologically before they were released for use. The latter precaution was instituted when it was found that certain pools of plasma that were free from bacteria when examined within 3 to 7 days after collection and processing were later found to be contaminated. Up to 1 November 1940, 1,950 litres of plasma were sent abroad as sterile after examination in Dr. Meleney's laboratory and 30 litres had been discarded because of contamination. The delayed contamination just described was discovered soon after this analysis had been made, and more rigid bacteriologic controls were at once set up. The total figures show that of 6,151 litres of plasma produced, 361 litres were found contaminated at the various hospitals and 160 litres were found contaminated in the central laboratory, the combined loss from contamination (exclusive of the amounts found contaminated in England) being 8.5

percent. The total loss from all causes was 581 litres, 9.4 percent; 151 bloods were rejected because of serologic evidence of syphilis (1.03 percent).

**Analysis of Operation**

The original opinion that the collection of blood and the separation of plasma would be "as simple as mixing a cocktail" promptly proved fallacious. The mass production of liquid plasma and its shipment abroad were very different from the production of small quantities for immediate local use. There were long debates on the size and shape of the collecting bottles, the stopper, the collection of blood by vacuum versus suction versus simple venous pressure, and the technique of removal of supernatant plasma. There were also discussions about the criteria for donors. Eventually, the age range was set at 21 to 60 years inclusive, the systolic blood pressure at 110 mm. Hg, and the haemoglobin level at 80 percent. Fasting was considered desirable, but the requirement proved impractical.

To set up criteria for production, to develop standard techniques, and to insure the safety of the final product involved far more difficulties than could be solved by volunteer part-time workers, and Dr. Charles R. Drew, later Assistant Professor of Surgery, Howard University, was appointed full-time medical supervisor of the project shortly after it was initiated.

The New York experience with liquid plasma led to the later decision that dried plasma would best solve the problem of so-called blood substitutes for the Armed Forces because of its greater stability; the simplicity of its packing, storage, and transportation; and reduced losses from breakage.

The Blood for Britain project was a most valuable introduction to the later development of the American Red Cross Blood Donor Service (p. 102). The experience of the New York chapter served as a pattern for the organization and operation of the blood donor service which was to supply plasma for the Armed Forces and blood for overseas shipment. This chapter was ready to begin operations as soon as the Surgeons General of the Army and the Navy requested the American Red Cross to be responsible for the blood donor program.

There were many mistakes made in the operation of the blood and plasma program during the United States participation in World War II, but far more would have been made without the trial-and-error experience of the Blood for Britain project. The chief lesson learned was that blood and plasma, if they are to remain uncontaminated and safe for use, must be handled in a completely closed system. The vacuum system devised by Elliott in 1936 ended this particular problem *(36).* The gravity system of bleeding may be less damaging to red blood cells than a vacuum system, but only the completely closed system possible with a vacuum bottle insures sterility.

## THE BRITISH BLOOD PROGRAM IN WORLD WAR II

The Association of Voluntary Blood Donors founded in Great Britain in 1922 later became the British Red Cross Transfusion Service, the first organization of its kind in the world and the forerunner of a number of similar associations in Great Britain and elsewhere *(37).* Blood banks were in operation in various hospitals in that country for at least 6 years before the outbreak of World War II.

In the months after the Munich crisis in 1938, recent advances in transfusion techniques, especially the use of stored blood on the field in the Spanish Civil War, were under constant discussion in Great Britain *(32, 37, 38).* The Medical Research

Council, on behalf of the Ministry of Health, established four blood depots in the outer suburbs of London. Arrangements were also made to establish an Army Transfusion Service, which would enrol all available donors in the South-Western Countries and which would also supply civilian needs in that area.

In short, as Brigadier (later Sir) Lionel E. H. Whitby, RAMC, who headed the British blood program, expressed it, the British began the war with a firm policy, decided upon 6 months earlier, that there would be a completely distinct and separate transfusion service in the Army *(38).* Returning to the subject at a meeting of Allied medical officers on shock and transfusion in May 1945, he pointed out that the transportation of potentially dangerous biologic fluids over long distances requires close personal supervision and cannot be trusted to the usual supply routes from a base depot medical store (32).

The British blood program was a remarkably successful operation for the two reasons just indicated: (1) that it was carefully planned before hostilities began, and (2) that it was based on the concept that blood is a perishable fluid, as potentially dangerous as it is potentially useful, and therefore to be handled in special channels by specially trained personnel. The daily, almost hourly, care that trained British officers and men gave to the blood they handled reduced accidents to a minimum. The British also regarded it as essential that their armies be self-contained as regards blood. The success of the attempt in World War II, first made by the British in the Western Desert, to bring surgeons forward to casualties, was due in large part to the successful operation of the Army Transfusion Service.

A similar separate service was recommended by the Subcommittee on Blood Substitutes, NRC, for the U.S. Armed Forces early in U.S. participation in the war (p. 76). Such a service was later set up in Italy, and time, expense, and lives would have been spared if it had been put into operation when it was proposed.

**Functions of the Army Transfusion Service**

The chief function of the British Army Transfusion Service was to supply blood and other fluids, including crystalloid solutions, with equipment for their use, to the entire British Army overseas and in the United Kingdom, and also to supply civilian needs in the areas of the United Kingdom in which it operated. Liquid plasma was used in temperate climates and was safely exported as far as India; it was kept cool but not under refrigeration.

Dried human grouping serum was prepared by the Army Transfusion Service. It was selected because it did not require refrigeration. It was coloured with acriflavine for group A and with methylene blue for group B. The minimum titre was 1:32 against $A_2$ cells and 1:64 against B cells.

**Organization**

The British Army Transfusion Service (fig. 4) was organized on three levels: a home depot, which was chiefly a production and training centre; a base transfusion unit, which was chiefly concerned with distribution, in each theatre of operations; and field transfusion units, which worked in forward areas. The home depot, in addition to supplying transfusion fluids, was responsible for the mobilization, equipment, and training of transfusion units for service overseas and for the training of all ranks of the Royal Army Medical Corps in resuscitation work. The courses of instruction, which were begun in 1940, were attended by officers from the British Army, Navy, and Air Force; personnel from other Allied forces; members of the civilian Emergency Medical Service; and, later, many U.S. Army medical officers (p. 471). In addition to instruction in blood work, the courses included preparation and assembly of

crystalloid solutions, the maintenance and repair of transfusion equipment, refrigeration maintenance and repair, and autoclaving.

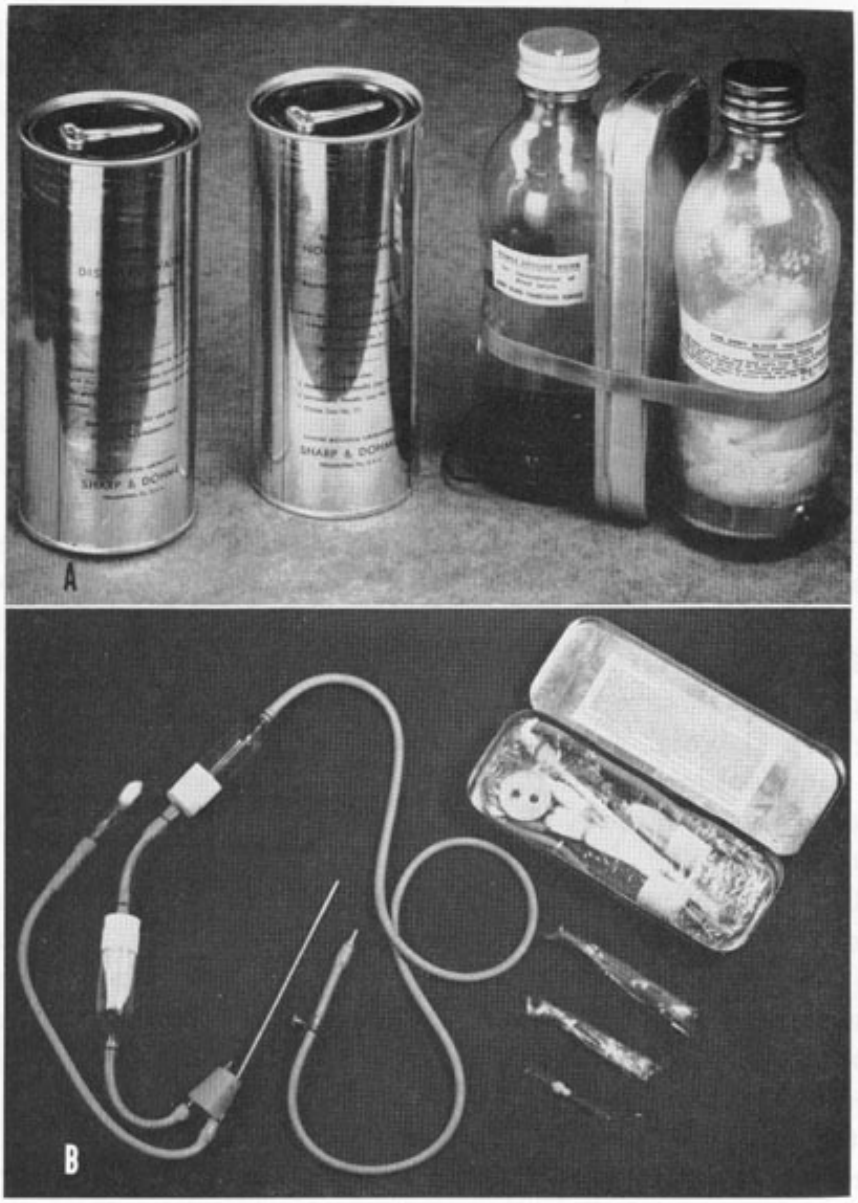


FIGURE 4.—British and Canadian materials and equipment for replacement therapy. A. British (right) and U.S. Army dried plasma units. B. British dispensing set for plasma.

Bleeding was carried out by 15 mobile, fully equipped, self-contained teams, each consisting of a medical officer, who frequently was a woman, 4 VAD's (Volunteer Aid Detachments); 2 ATS (Army Transfusion Service) drivers; and an ATS orderly. Each team had two vehicles, one a lorry equipped with an icebox, and the other a four-seated car. With the equipment carried, any room could be converted into a miniature hospital ward for bleeding within 20 minutes. For steady work, each team was expected to obtain 70 to 90 pints of blood daily. In emergencies, over short periods, these amounts were exceeded, and some teams collected as much as 300 pints daily.

The 440 cc. which made up each bleeding was collected in a bleeding bottle (fig. 4) into 100 cc. of 3-percent sodium citrate solution. Later, with special equipment, 20 cc. of 10-percent dextrose was introduced into each bottle, so that it was filled to the top and its contents were not agitated during transportation. Capping was done with a special machine.

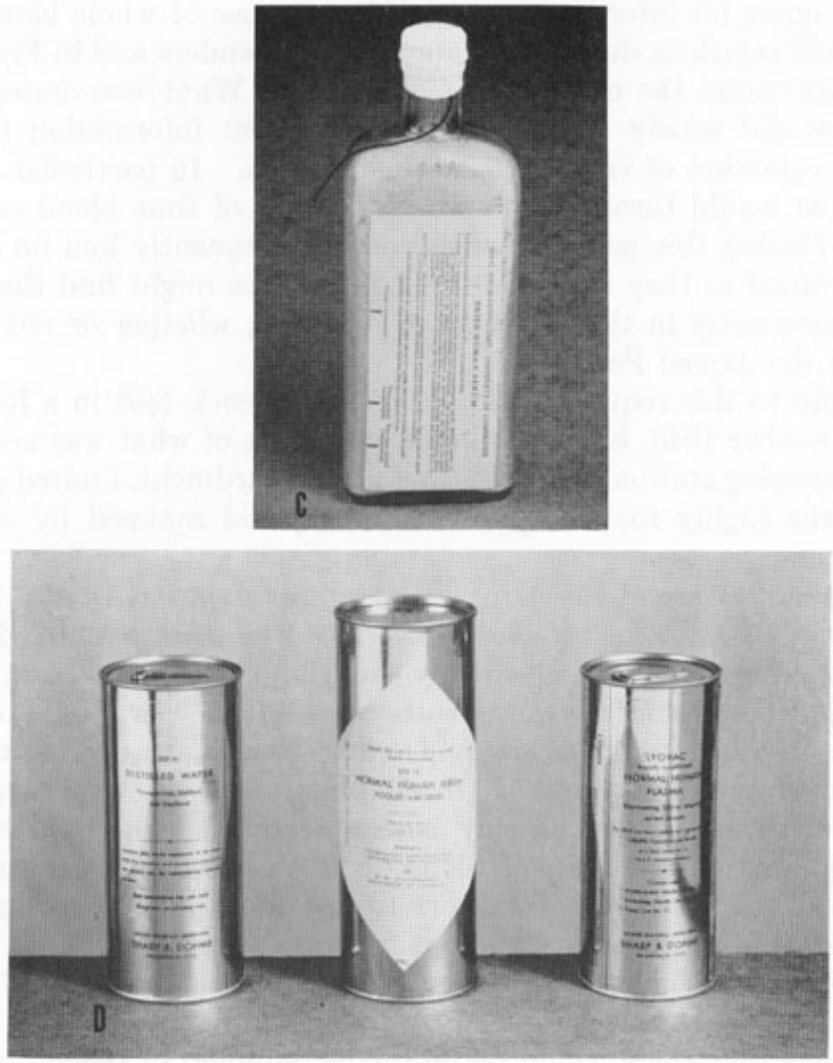


FIGURE 4.—Continued. C. Original British dried human serum unit, prepared at University of Cambridge. D. Canadian dried human serum unit (center), shown with distilled water and dried plasma units of U.S. Army. The Canadian package, which contained 250 cc. of serum, was as large again by a third as the U.S. plasma unit.

Only group O blood was used for overseas troops. It was tested by the Kahn test and double-checked for group before it was dispensed. Brigadier Whitby had no knowledge of the dispensing of any incorrectly typed blood during the entire war *(32).*

**Base transfusion unit**

The base organization overseas was the link between the home depot and the forward transfusion units. Its function was to estimate needs for replacement fluids; obtain supplies and equipment from the home depot; distribute them to forward

areas; produce crystalloid solutions; assemble apparatus; service and repair refrigerators; and exploit local resources, usually base troops, for blood donations.

When the base unit was within reasonable distance of the home depot, as it was in France, the home unit was responsible for the supply of whole blood. Otherwise, the base unit was responsible. Blood collected locally was sent forward to field units by road in refrigerated trucks, by air in insulated boxes, or along the coast in the refrigerators of hospital ships. Personnel of the unit were equipped to give transfusions, but their multiple duties usually prevented any large-scale performance of this function.

**Field transfusion units**

Field transfusion units, which were the smallest units in the British Army, were entirely self-contained and were fully equipped for transfusion in the field. Their personnel consisted of an officer and three men, one of whom drove the truck and was entirely responsible for the operation of the refrigerator, upon the efficiency of which the safety of the blood depended. These units, which were attached wherever they were most needed during a campaign, usually operated with field surgical units, the combined units forming complete surgical centres at field ambulances, field dressing stations, and casualty clearing stations. Surgeons came to rely heavily upon these field transfusion teams; many of them delegated the selection of their operating lists to them. The optimum time for surgery, Brigadier Whitby pointed out, was often "a fleeting moment indeed," and the teams working on the wards, with their skill in resuscitation, were often best equipped to pick that moment *(32).*

**Experience in France, 1940**

During the so-called phony war, the personnel of the Transfusion Service utilized the time developing a large donor panel, which eventually included more than 350,000 names; carrying out studies on the keeping properties of blood, especially when it was transported overseas; determining the merits of various blood substitutes; and developing a technique for the filtration of plasma.

This was a difficult period for the Transfusion Service. It was necessary to bleed donors to provide for possible needs, but at the same time impractical to build up a reserve. Blood was sent to France by air, and later was flown to Norway, where it was flown directly to transfusion units operating in forward zones.

About 400 units of stored blood seem to have been used on the Continent between the invasion of the Low Countries on 10 May and the Dunkirk evacuation. In an editorial in the *British Medical Journal* on 10 August 1940, a request was made for information concerning the use of whole blood, plasma, and crystalloid solutions during the campaign in Flanders and in France, when conditions prevented the collection of data *(39).* What was desired was not data "that would satisfy medical statisticians" but information that would permit the evaluation of various replacement fluids. In particular, data were requested that would throw light upon the length of time blood could safely be stored. During this period, medical officers frequently had no choice but to use such blood as they had, and other physicians might find themselves in similar circumstances in the frontline at any time, whether or not they were serving with the Armed Forces.

The reply to this request, from W. d'A. Maycock *(40)* in a letter to the *Journal,* 5 October 1940, is a remarkable statement of what was accomplished in casualty clearing stations subject to aerial bombardment, limited in numbers because of the highly mobile type of warfare, and manned by overworked medical officers:

The rapid response of the Army blood supply depot at Bristol to requests made immediately after the invasion of the Low Countries permitted the stocking of mobile refrigerators, in which only small supplies of blood had previously been stored, at the casualty clearing stations. Within 4 or 5 days, each of the eight teams attached to these stations and the teams attached to the medical base at Boulogne had received 60 to 80 pints of blood, with some plasma. Glucose-saline solutions had already been stockpiled. One casualty clearing station designated as an advanced blood depot was provided with extra quantities of blood and was given transport to distribute it as necessary to other stations. Some forward units could not function at all.

The provision of apparatus for transfusion with each bottle of blood was ideal for active service and permitted transfusion under almost any conditions. The knowledge that there would be no further supplies of blood made officers use what was available very conservatively, and it was withheld from casualties who in happier circumstances would surely have received it. Transportation of blood for long distances over rugged roads did not seem to increase haemolysis, and there was no known instance of serious infection after a transfusion, even though the blood was often injected without regard to asepsis or antisepsis. No serious reactions were reported after transfusions with blood 3 weeks old and, in one instance, 7 weeks old, and amazingly good results were often obtained in apparently moribund casualties.

**Clinical Considerations**

At the Conference on Shock and Transfusion, 25 May 1945, Brigadier Whitby noted that between that date and 1939, the pendulum had swung back and forth on a number of points (32):

1. Early experience with air raid casualties suggested that the necessary volume of transfused fluid was often almost incredibly large. Then came a wave of apprehension that these quantities were producing pulmonary oedema, as in some instances they were. The amounts administered in shock and haemorrhage had now become stabilized, but seriously wounded casualties, especially those with massive wounds of the extremities, still required very large volumes of replacement fluids.
2. It was now well understood that plasma had its optimum usefulness in forward areas, to restore and maintain the efficiency of the circulation. Only whole blood transfusions, however, could render a casualty fit for surgery.
3. Speed in administration was essential. If a casualty was exsanguinated, an experienced resuscitation officer would have blood going into two veins at once. There was no danger of pulmonary oedema at this time.
4. Blood and plasma were supplied so generously to the Armed Forces that if a casualty were wounded at all, he was fortunate to "escape" transfusion, even if he did not need it. It had been learned that, at least in wounds of the chest and of the central nervous system, blood, if given at all, should be administered with great moderation. In extremity wounds, although transfusion was needed, it introduced the risk of fat embolism.

Col. Frank B. Berry, MC, Consultant in Surgery, Seventh U.S. Army, supported Brigadier Whitby's warning about the unwise use of blood by the specific illustration of a casualty with blast injuries of the head and lungs whose life was saved in these circumstances only because he had a haemorrhage from the iliac artery.

## THE SOVIET UNION BLOOD PROGRAM IN WORLD WAR II

While not a great deal is known about replacement therapy in the Soviet Union during World War II, all reports indicate that blood was the chief replacement fluid *(41-43).* This might be expected because of the large civilian population; its proximity to the frontlines; the cold climate, which eliminated many of the difficulties of preservation and storage; and, perhaps, the lack of facilities for processing blood to plasma or serum (p. 95).

The nationwide transfusion service that existed in the Soviet Union before the war was organized in Moscow in 1926, by Lt. Col. Andre Arkadievich Bagdasarov. This officer later directed transfusions under fire during the border warfare with the Japanese in 1939 and during the war with Finland in 1940-41.

The Central Institute for Blood Transfusion in Moscow was at the head of several subordinate institutes and about 1,500 blood donor centres. When Russia entered World War II, this organization became, in effect, a system of factories for collecting and preserving blood and delivering it to the front as it was needed.

About 2,000 persons a day gave blood in Moscow, about the same number who donated at the two blood centres in New York. All possible methods of "sanitary" propaganda were used to attract donors. About 95 percent of the donors were women, as compared with 50 percent in the United States. Donations ranged from 225 to 450 cc. A second donation was permitted in 4 to 6 weeks, but only if the blood picture had returned to normal. With these precautions, some donors had given blood for periods of 12 to 15 years with no ill effects.

A standard four-cornered container was used to collect and administer blood. The bottles were transported, preferably by plane, in specially constructed isothermic boxes, suitable for use in both warm and cold weather. Blood was also put up in 200-cc. ampules which could be carried by medical corpsmen and used well forward.

The Russians used type O blood for most battlefield transfusions and also used large amounts of type-specific, unpooled plasma. The institute worked out a method which permitted the preservation of blood for 3 or 4 weeks without loss of its biologic properties and also devised a technique for drying plasma that insured its solubility without turbidity or precipitation.

Transfusions were given at all points up to the regimental medical aid station (battalion aid station) but were most widely used at the medical sanitary battalion service level (collecting station). The most important indication was haemorrhage with shock, especially in wounds of the abdomen and extremities. The combined experience of the institute and the army was that only large transfusions, from 1,000 to 1,500 cc., given rapidly, were effective in shock.

## THE GERMAN EXPERIENCE IN WORLD WAR II

When the blood program originated in Germany is not entirely clear. A civilian program was set up in 1940 by an administrative law which permitted donations of only Aryan blood and which provided for payments of 10 marks for the first 100 cc. and 5 marks for each additional 100 cc. *(43).*

The military procurement program was apparently an outgrowth of this civilian program. The Laboratory for Blood Transfusion in Berlin, which directed the military

program, was disrupted by heavy bombings, and all the evidence suggests that the supply of blood was insufficient and that containers and technical equipment were in short supply.

Donors included medical personnel, nursing sisters, staff assistants, and slightly wounded men. An endeavour was always made to rule out tuberculosis, malaria, and syphilis in donors, but serologic examinations were seldom practical and the donor's statement that he had not had syphilis usually had to be accepted. Blood groups entered in the soldiers' pay books were frequently incorrect, and new determinations had to be made before each transfusion. If this was not possible, a test injection of 10 cc. of blood was made.

The German experience with preserved blood was chiefly between 1940 and 1942. There were so many serious reactions that medical officers lost interest in it. Those who reported satisfactory results were usually in favourable positions, along the lines of transportation. Some medical officers had never seen preserved blood used in the field without "deleterious" chills. Plasma and serum were seldom used, although officers who used captured U.S. stocks of plasma were enthusiastic about it.

**Special report**

After the German surrender in Italy on 1 May 1945, an unusual opportunity arose to study German management of battle casualties *(44).* On the instruction of the Fifth U.S. Army Surgeon, Lt. Col. (later Col.) Howard E. Snyder, MC, visited a number of German medical installations, including the equivalents of U.S. field, base, and convalescent hospitals. In his report, which is included in detail in another volume of this historical series *(44),* Colonel Snyder emphasized that observers could not judge the standards of German medical practice in the first years of the war in the light of what they found in May 1945, after the total collapse of the Army, nor could they judge the quality of German medical practice elsewhere in Europe in the light of what they found in Italy.

The German management of shock and haemorrhage was thus in sharp contrast to the U.S. practices, by which plasma was always available, and was used in the quantities indicated, in all forward medical installations, while banked blood was available in adequate quantities in field hospitals adjacent to division clearing stations. The extreme pallor of many of the wounded observed in German hospitals, and the moderate pallor of most of the others, supported the deduction that they had received little if any blood.

## OTHER SOURCES OF BLOOD

To complete the record of the status of transfusion at the beginning of World War II, three other possible sources of whole blood should be briefly mentioned; namely, blood secured from the patient's own blood, that is, auto-transfusion; cadaveric blood; and placental blood.

**Auto-transfusion**

Auto-transfusion (autohemofusion, autoinfusion) was first suggested by Highmore in 1874, as a sort of afterthought in a fatal postpartum haemorrhage *(45).* Halsted, in 1884, treated several patients with carbon monoxide poisoning by drawing blood from the victims, defibrinating it, and then re-infusing it. Auto-transfusion was apparently first employed in trauma by Duncan of Edinburgh in 1885, in an amputation for a crushing injury of the leg *(1).* The patient, who was close to death at the end of the operation, made a rapid recovery.

In 1923, Burch *(46)* collected from the literature 164 cases, chiefly from Germany, in which this method had been used, and several other large collections were made during the next several years. Auto-transfusion proved particularly useful in ruptured ectopic pregnancy. Most of the unfavourable reactions and some of the fatalities could be explained by the fact that the blood had been in serous cavities for periods up to 72 hours before it was used.

In World War I, according to Yates *(47),* the large amounts of blood and "coloured fluid" removed in massive hemothoraces suggested the possibility of auto-transfusion, but tests showed that the attendant risks were prohibitive and the method was not used.

Auto-transfusion, naturally, became less necessary as blood banks were set up, but early in World War II, when blood was still in short supply, it proved a valuable method in occasional severe chest injuries in which it was certain that there was no injury of the abdominal viscera.

**Cadaveric blood**

In 1928, Shamov reported the experimental use of cadaveric blood and demonstrated the absence of toxicity *(48, 49)*. At this time, Yudin was in charge of the entire surgical and accident department of the Sklifosovsky Institute, the central hospital for emergency surgery in Moscow, in which from 8,000 to 10,000 patients were treated every year. The admissions also included many patients who died promptly from acute cardiac disease or severe trauma. In other words, the patients who needed transfusion and the bodies from which, in the light of Shamov's demonstration, the necessary blood could be secured, were both at hand.

Yudin reported his first seven transfusions with cadaveric blood at the Fourth Congress of Ukranian Surgeons at Kharkov in September 1930. The work was investigated by two commissions, one legal and the other military, both of which recognized its scientific foundation, and he was given a special permit to collect blood from fresh cadavers before autopsy.

With the discovery that cadaveric blood could be stored safely, time was provided for both serologic tests and bacteriologic examinations. In November 1932, Yudin reported to the Société Nationale de Chirurgie in Paris on 100 transfusions with cadaveric blood kept for 3 weeks, and in one instance 4 weeks. In 1937, he reported in the *Lancet* that he had performed a thousand transfusions by this method, chiefly for internal haemorrhage and traumatic shock and in operations for gastrointestinal disease, particularly cancer.

In Yudin's first 200 transfusions, all performed with citrated blood, there were 40 reactions, all moderate. In the next 800 transfusions, all performed with non-citrated blood, the incidence of reactions fell to 5 percent. The five fatal cases in the series were explained in three instances by technical errors, including the transfusion of incompatible blood. The fourth death was due to embolism and the remaining death to anaerobic infection.

Cadaveric blood was apparently never used widely, even in Russia. It was not mentioned to Dr. George K. Strode *(42)* of the Rockefeller Foundation, who visited the Central Blood Transfusion Institute of Moscow in October 1941, and no statement in the literature suggests that it was used during the war. It is doubtful that transfusions with blood secured from cadavers could ever have been employed in any country in the world except Russia, for the idea, in spite of its logic, is revolting.

**Placental blood**

In February 1938, J. R. Goodall of Montreal, with a group of his associates, published a communication whose title proclaimed "an inexhaustible source of blood for transfusion" *(50).* This source was the placenta, from which amounts of blood ranging from 100 to 150 cc. had been collected under sterile precautions. The preservative used was the solution proposed by the Moscow Institute of Haematology (sodium chloride, sodium citrate, potassium chloride, magnesium sulphate, double-distilled water), and the blood had been kept in a refrigerator as long as 60 days at temperatures of 33° to 38° F. (1° to 3° C.). Serologic tests were not necessary, as they had been run on the mothers. Cultures were not considered necessary: the reasoning was that at the low storage temperature, contamination, if it was present, could not propagate and would be so attenuated as to be innocuous.

The Goodall report gave no definite figures but stated that "many" transfusions had been accomplished with placental blood with no reactions of any kind. It was concluded that the maternity section of a general hospital could provide blood for the whole hospital, supply other institutions, and also prove a source of income, since private patients could be charged for the transfusions. In the opinion of the Montreal group, placental blood could be regarded as a "safe, constant, efficient, and lucrative" source for transfusion.

Boland and his associates *(51),* reporting in the *Lancet* in February 1939, were considerably less enthusiastic about placental blood. They had experienced several serious reactions with it and found contamination in 30 percent of 40 specimens of foetal blood collected by the Goodall technique.

Placental blood was never used in the United States, and it was not employed in World War II.

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