How Transfusion Moved from the Margins to the Mainstream of Medicine, from World War II to the Pandemic

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INTRODUCTION

This book sets out to describe the changes that have occurred between two major events. World War II officially ended on September 2, 1945. Emergency declarations for the COVID-19 pandemic in the United States ended May 11, 2023.

It's the nearly 78 years in between that we treat in this book. That's a long time, long enough to be tempted to regard the book as a history.

From the start, we've thought of this work differently. It's an account of many–certainly not all, but many–of the bigger events in blood banking and transfusion medicine. It's a field that existed before WWII, but very much on the margins of medical practice. Today it's a huge field, present everywhere, playing a central role in the care of ill and injured people.

Rather than a definitive history, what you will read is a story of tremendous progress. We started with World War II, because it is breakthroughs in our society's ability to support soldiers on the battlefield in wartime-breakthroughs in preservation, storage, logistics-that enabled blood banking to thrive in the homeland in the years and decades to follow.

But the original baseline was modest. Coming out of WWII, we could collect blood, but could not extract its components. There was almost no infectious disease testing, because there was almost no knowledge about what diseases could be transmitted via transfusion. There were no organized networks that enabled blood banks to coordinate their efforts, and to enable covering shortages in one community with surpluses in another. There were no national professional associations, to advocate for the field, and to promote technical and scientific inquiry. There was not even the slightest suggestion that blood banking might have something to contribute to other fields, such as organ transplant.

Today's landscape is dramatically different in these and other regards. Dramatically different, and dramatically better. How society, and medical practice, got from there to here is the story we set out to tell.

To be sure, there were stumbles, missteps and worse along the way, and we included them in our accounting of these 78 years. For example – if you

were a parent of a hemophilia-afflicted son in the 1970s and early 1980s, your family saw the thrilling miracle of Factor VIII concentrates turn into the nightmare of a 50% likelihood of acquiring HIV because the plasma used to produce Factor VIII pooled the donations of hundreds or thousands of donors. This and other darker times are discussed along with the big victories and the advances in practice.

While we tried to provide abundant facts, we did not obsess with getting every last date pinned down. We named a lot of heroes who were behind the important advances, but we left out many more. And because we did not intend this to be a work of academic scholarship, while we consulted the peer-reviewed literature (and also books, media and other documents) extensively, we provide many references at the end of nearly all chapters, rather than numbered citations.

We also want to anticipate critics, who might point out, correctly, that our book treats events in the last couple of decades much more lightly than those of the 20th century. While we plead guilty, we want to make a couple of points. First, the sturm und drang of the last two decades of the 20th century had calmed down. There were no antagonists – blood centers pitted against blood centers, Red Cross against AABB, the industry against the Congress or the FDA or critical journalists or activists, blood providers against health care system financial officers–creating the drama of earlier times. But additionally, as we write this book in 2022 and 2023, it's also the case that to comment on any past events some perspective, some time is needed. So, whatever is important from the early years of the 21st century may be better commented on and judged in another 20 years.

Blood banking and transfusion medicine have come to occupy a vital place in patient care, and we're glad to contribute a book that tells a lot of the story of how that came to be.

—JJM and DJT

PART 1

THE BASICS

CHAPTER 1

SELECTED ACTIVITIES DURING THE WAR

The end of World War II (WWII) was chosen as the starting point for this book for a reason. It's true that in previous armed conflicts, combatants were sometimes supported with blood transfusion. It's also true that some transfusion activity occurred for treatment of patients in hospitals in the United States before WWII. But these treatments were on a small scale, usually ad hoc, often done through direct donor-to-patient means, sometimes born of desperation. The Second World War, however, produced scientific and logistical breakthroughs that set the stage for development of full-scale transfusion capabilities in large and small communities throughout the United States, after hostilities ended.

Wartime Activities That Formed the Basis for Postwar Activities

The sections that follow, along with Table 1-1, summarize some significant developments during wartime.

Table 1-1. Selected Activities during WWII That Formed the Basis for Ongoing Postwar Activities

Standardization of ABO typing
Production of large amounts of ABO typing sera
Increased understanding of the clinical impact of Rh antibodies
Development of a structure for large-scale blood collection, transportation, and inventory management
Establishment of the clinical value of whole blood
Preservation of red cells, allowing 21-day storage
Establishment of the clinical value of plasma
Use of type O blood for non-O recipients

Plasma for Britain Program

After France fell to Germany, Dr. Alexis Carrel, the brilliant French physiologist who, at 39, was the youngest recipient of the Nobel Prize for science, returned to New York and advocated the need for plasma for Europe. The Blood Transfusion Association of New York convened a meeting involving a number of entities, including the American Red Cross. The cooperation of the New York chapter of Red Cross was immediately engaged, and the Plasma for Britain program became operational in August 1940 at the Presbyterian Hospital in New York.

National Blood Program System

A surgeon, Dr Charles Drew, was called back to New York from Howard University in September 1940 to direct the Plasma for Britain project. Great Britain, then under attack by Germany, was in desperate need of blood and plasma to treat military and civilian casualties. In August, Presbyterian and five other New York hospitals had begun a collaborative effort to collect blood and ship the plasma. Although others had developed the basic methods for plasma use, Drew, as medical director, instituted uniform procedures and standards for collecting blood and processing blood plasma at the participating hospitals. When the program ended in January 1941, 14,556 pints of blood had been collected. Drew was then appointed assistant director of a pilot program for a national blood banking system, jointly sponsored by the National Research Council and the American Red Cross. Among his innovations were standard ways of evaluating donors and of collecting blood and storing it, and mobile blood donation stations, later called "bloodmobiles." Mobile units, or bloodmobiles, were established and used extensively, with the estimation that 47% of all blood donations occurred through them. They operated within a radius of 75 miles of the 35 centers, and it was estimated that their use brought 60% of the US population within range of blood donor services.

Bloodmobiles were all the same kind of truck and had standardized equipment, including folding carts and portable refrigerators. Boxes of supplies were packed so that the collection operation could be set up very quickly once the destination was reached—usually a schoolhouse, assembly hall, church, or space in military or industrial establishments. Interestingly, the situation is not much different today. By the end of the war, it was estimated that mobile units were being operated in 60 different places. The local Red Cross chapters made all of the arrangements for the bloodmobile visit.

As the blood bank effort expanded in preparation for America's entry into the war, the armed forces initially stipulated that the Red Cross exclude African Americans from donating. Ironically, Drew, a leading expert in blood banking, and who was African American, thus was ineligible to participate in the program he helped establish. The policy was soon modified to accept blood donations from African Americans, but required that these units be segregated. Throughout the war, Drew criticized these policies as unscientific and insulting to African Americans.

Because of the efforts of Drew, the Red Cross blood donor service was translated almost overnight from a limited peacetime activity to a major national contribution to the military effort.

During the war, the Red Cross effort was led by Dr. Canby Robinson, who later became dean of the medical school at Vanderbilt University. The interest in bringing an outstanding biochemist into the blood program resulted in Edwin Cohn joining. His laboratory at the department of biochemistry at the Harvard Medical School was credited with the successful fractionation of blood plasma and the development of serum albumin.

The United States was slow in setting up the whole blood program. O. H. Robertson had stated unequivocally from experience in World War I and the Spanish Civil War that when blood is lost it must be replaced by blood. The British had established that there would be a distinct and separate transfusion service for the armed forces because of the difficulties of transporting biologic fluids over a long distance. This proved to be remarkably successful. It was almost three years before blood began to be flown overseas from the United States to the European and Pacific theaters. Once the airlift was initiated, it was clearly demonstrated that blood could be collected thousands of miles from its point of use, safely transported, and used with safety and benefit if there was proper planning and handling, proper timing, adequate airlift, and careful coordination. Successful use of whole blood reached a high point in Okinawa. Planning was detailed and timely. Airlifts provided blood in ample quantities. There were 40,000 casualties, whose treatment involved the use of approximately 40,000 pints of blood. All the blood used in Okinawa was flown from the United States, a distance of 5000 miles. With outdating set at 21 days, it required careful timing to ensure provision of an adequate quantity of whole blood with a minimum amount of wastage.

ABO Typing

At the beginning of the war, ABO typing was not standardized, and this led to a variety of results, some of which were erroneous. It was rather quickly learned that the red cell suspension and temperature and duration of incubation could lead to differences in results. The procedure was subsequently standardized, and by the end of the war, ABO typing was quite dependable and consistent. Some of the work to standardize these techniques was done by Elmer DeGowin. Typing was done initially using rabbit serum, but as need increased, efforts evolved to work with human serum. Once again, Dr. Cohn's method for plasma fractionation proved helpful. Dr. John Elliot, for whom the blood bank in Miami, Florida was later named, was placed on temporary duty to develop a new technique for preparing ABO typing serum from human plasma using the Cohn process. This activity was successful, and adequate amounts of ABO typing sera were available throughout the war thanks to DeGowin and Elliott.

Rh Typing and Rh-Negative Blood

In 1940, Landsteiner and Wiener demonstrated that incompatibility could occur within the same ABO blood group. They injected rabbits and guinea pigs to identify a serum they referred to as Rh. During much of the war, Rh typing of donor units was not performed, and blood was transfused based only on ABO type compatibility. Crossmatching was not done. As the war progressed, it was not uncommon that patients would receive multiple transfusions over a period of time. Some of these subsequent transfusions caused reactions, which at first were thought to be pyrogenic, but later it became clear that some of these reactions were due to the Rh factor. Survival of transfused incompatible red cells was decreased, but it was clear that the first series of transfusions could be given without adverse effect from Rh. The severity of the subsequent reactions depended on the amount of Rh antibody in the patient’s blood, although this was not well understood until later.

A difference of opinion developed whether Rh considerations were important in battlefield transfusion practices. The prevailing view was that the likelihood of reactions at the age of military personnel was very small, that emphasis should be put on the indications for transfusion, that the pyrogenic reactions and hemolytic reactions result from ABO mismatches, and that Rh should be given very small priority. It appears that some Rh testing might have been done but probably not integrated into routine operation because of the scarcity of sera and the fact that the test took about

an hour and results were undependable.

Another factor complicating Rh typing and matching was that when testing became available in rear or secondary facilities, the problem of confusing typing surfaced because patients would have already received large amounts of Rh-positive blood before arriving at the treatment facility.

Other Testing of Donated Blood

Some testing was done for syphilis and for malaria. Because all military personnel were tested for syphilis during their initial training and because they were in combat and not likely to become infected, the results of that testing were used. In February 1941, the National Institutes of Health recommended that syphilis testing be done on blood taken at the time of bleeding. But subsequent discussions led to some modification of this recommendation: that, alternatively, blood could be stored for 72 hours, at 4 degrees C. before transfusion because of the recognition that the spirochete survived for only about 92 hours in stored blood. (The authors have not been able to establish why 72 hours, rather than 92, was deemed sufficient.) Also, because blood was drawn under a variety of conditions during combat, sometimes it was not necessary and not possible to perform an appropriate syphilis test, and so the results of previous testing of the donor were used. The authors were not able to find data on the overall portion of blood that was tested for syphilis during the war, but no reports of transfusion-transmitted syphilis were found.

Syphilis testing was not performed on each donation. This was partly because it was just not practical. To do this kind of large-scale syphilis testing, in multiple locations, and to obtain results quickly, when possible, donors were tested for syphilis during the donation process. The authors were not able to find data summarizing the overall portion of transfusions during WWII that were tested for syphilis.

The issue of testing for malaria was rather complex. In many theaters of operation, malaria was not a concern, so testing was not considered. However, in other areas of endemic malaria, this became an important issue. It was clear that malaria could be transmitted by blood transfusion. Some donors were also tested for malaria, based on the location of the conflict where the blood was being collected. A considerable amount of research was done during the war on malaria parasites in plasma and albumin. Malaria was considered a hazard. Although studies showed that only 5 to 10 mL of infected blood could transmit infection, it was projected that

parasites would survive in large quantities of blood for 2 to 3 weeks. Transmission of malaria had been reported from donors who had been clinically cured for 15 years. Thus, the general recommendation was that accurate history on possible malaria infection should be obtained from all donors, especially those whose blood was intended for preparation of packed red cell units. Any donor with a history suggesting the possibility of malaria infection would not be accepted. Laboratory testing for malaria in individual donors was not performed. The authors were not able to find any reports of transmission of malaria during the war, although such transmission seems probable.

Treatment of Shock and Blood Loss

World War II was the first war in which blood was used with frequency, and the first in which plasma and albumin were used at all. Blood was collected into glass bottles and thus pyrogens and pyrogenic reactions were a major problem.

An abundance of plasma was available in the "sterile pyrogen free dispensing sets and distilled water supplied with it permitted the administration of large quantities without fear of reaction. It has been estimated that the use of plasma saved in the hundreds of thousands of lives." Anyone living today who is the son or daughter of a WWII veteran may want to reflect on this figure.

In the beginning of the war, the concept of shock was not well defined. "Transfusion was a dramatic and heroic procedure resorted to more often than not only when the situation was critical or desperate. "Direct donor-to-recipient transfusion was just beginning to shift to indirect methods, but this was restricted, primarily because of pyrogens in the collection sets and the glass bottles.

Use of Whole Blood

Dr. Elmer DeGowin, for whom the blood center at the University of Iowa was later named, was an early and strong advocate of the necessity of using whole blood and for the need to begin to develop a supply of whole blood to the Armed Forces. As anticoagulant/preservatives were being developed (see later section), experience was gained with the use of whole blood for large blood-loss situations. Experience was gained using 3 to 4 liters of blood within 12 hours, and Michael Debakey (who later became a famous cardiac surgeon) reported successful transfusion of 9 liters in 12 hours. In order to make blood more readily available, there was considerable interest

in using type O blood in non-O patients. Because this was whole blood, there was concern about the amount of plasma containing anti-A and anti-B, so a method was developed to test for units that contained high titers of these antibodies. John Elliott developed a simple, effective method in which dried type A and B blood was used to screen donor blood. The test worked quickly and was put into production by Wyeth, and later by Cutter, Laboratories.

Use of Plasma

In some situations, the plasma was removed from the original unit of whole blood and used separately for transfusion. The plasma could be stored and transported more easily, thus making replacement fluid more readily available. At that time, plasma was not used as much for hemostasis but instead for volume replacement. This development was possibly a forerunner of blood components, which would come a decade or two later.

Use of Albumin

A technique to fractionate plasma had been developed by Edwin Cohn of Harvard University in the late 1930s. This method allowed isolation of five major fractions of plasma, including albumin. It was quickly recognized that albumin, due to its osmolality, could be a valuable transfusion product for blood loss. The government provided a large amount of money, as did some private pharmaceutical companies, and the Plasma Fractionation Laboratory was established to produce large amounts of albumin. Thus, rather early in the war there was availability of whole blood, plasma, or albumin for the management of blood loss. The major clinical benefit of this fluid replacement strategy was recognized early in the war. The early use of these replacement fluids was led and advocated by Dr Elliott and Dr DeGowin. Many modifications of the original cold ethanol fractionation process have been developed and implemented subsequently, but the availability of this process from a biochemistry laboratory at Harvard undoubtedly saved lives.

Anticoagulants

Before World War I, Rouse and Turner developed the first red cell storage solution when they were working with rabbits. This storage solution was a simple mixture of citrate and glucose, and they used it for research purposes. Somewhat later, Rouse's fellow O. H. Robertson used the Rouse Turner solution to establish a successful blood bank at the Harvard Medical Unit attached to the British forces in France. DeGowin developed a modified solution of trisodium citrate and dextrose with a volume of 650 mL; thus,

when blood was added, there was total volume of 1150 mL. Concern about damage to red cells from trauma during transportation was alleviated when DeGowin shipped units of blood in his solution from the University of Iowa to San Francisco and elsewhere for up to 30 hours with no evidence of hemolysis. John Alseiver developed a solution of sodium chloride-sodium citrate and glucose 500 mL, which resulted in a unit of blood of 1 L. Because there was more experience with this solution than others, the Alseiver solution was used in the blood supply for the landings in Normandy. One drawback to the mixture was that it could not be heat sterilized because the glucose caramelized. During World War II, Mollison improved the situation by adding citric acid, which lowered the pH and allowed sterilization of the solution without caramelization. This preservative solution became known as acid, citrate, dextrose, or ACD, which was used for many years. Citric acid and glucose with sodium citrate were the mainstay of blood preservation during World War II and a few years after. This is the fundamental structure of current blood preservation. Post war developments enabled storage of red cells for up to 35 days.

Storage

It had been known before the war that if blood was to be kept for more than a day or so, it had to be kept cold. The exact temperature and tolerance for temperature fluctuation were not known. This became a major issue as the war progressed, and it became necessary to ship blood from the United States to Europe and the Pacific. This led to considerable discussion regarding storage in refrigerators in preparation for the invasion of Normandy. Refrigerated containers had been developed for ground transportation. They were insulated boxes that had a need for battery power or gasoline motors. It was projected that each flight to Europe could transport 450 units of blood in refrigeration, or 900 if not in refrigerators. Because temperatures are cold at high altitudes during flight, there was more concern about damage from cold or freezing than from warming. It was decided not to use refrigerators but instead to train the pilots how and when to turn on the heat in the plane to keep temperatures at less than 10 degrees during flight—moderate but not too hot or too cold. Thus, under the leadership of John Elliott, they were able to transport blood from the United States to Europe and later to the Pacific, preserving it successfully while shipping twice as much blood as would have been possible if transportation in refrigerators had been necessary.

Red Cross Blood Program

Some of the Red Cross blood activities began before the United States entered the war on December 7, 1941, immediately following the bombing of Pearl Harbor. The requirements for blood in that earlier period were not large. It is estimated that 28,974 pints of blood were procured during the period of 10 months between the institution of blood donor services and the Pearl Harbor bombing. Immediately after Pearl Harbor, donations increased drastically and a similar situation occurred after the invasion of Normandy. For instance, during the week of the Normandy invasion, 123,284 pints of blood were collected and thousands of future appointments for blood donation were made. The flow of information about the war provided free publicity but sometimes had counterproductive results, as observed with later tragedies such as 9/11. For instance, immediately after the Normandy landings, when the news indicated that casualties had been fewer than anticipated, donations declined but resumed with the publicity concerning the difficulties in the liberation of France. A principle established then remains true today: General publicity about the need for blood must be supplemented with specific person-to-person recruiting techniques and scheduling of donors.

Also similar to present times, in the operation of each blood center and mobile unit there was a strict system of weekly quotas. There had to be enough blood, yet storage considerations did not allow for surpluses to be built up; there needed to be a regular flow of donors every day. As much then as now, as blood programs aimed for this regular and predictable flow of donors, external factors also came into play. In December 1943, plasma donations were 40% short of the goal because of an epidemic of influenza. In February 1945, a blizzard in the east almost eliminated donations for several days. Similar experiences still frustrate the most careful of plans and create difficulties with blood inventories.

Another issue still prevalent today is the difficulty created by donors who either cancel their appointments or fail to appear. This leads to a waste of time—valuable time—because it keeps other potential donors from using that time scheduled. About 10% of donors who appeared for their appointments also had to be rejected for various physical reasons, so for these other reasons it was necessary to enroll about 150 donors for each 100 units of blood expected to be collected. This meant that the 13,326,242 pints of blood collected during the war by Red Cross required the scheduling of nearly 19 million appointments. Some individuals made multiple donations. It was estimated that the average donor gave 1.2 pints, about 1.5 million

gave three donations, 150,000 gave a gallon, and about 33,000, two gallons or more. These multiple-donation donors were effective in dispelling the concern that giving blood might be harmful.

All donations were voluntary, but a trial plan for inducements in the spring of 1943 was the offer of tickets in Brooklyn for Dodger baseball games. However, the public reaction was instant and adverse, and the plan was discontinued on the third day. By the end of June 1942, the Red Cross had collected 461,493 pints of blood.

During the war, particular attention was paid to protect against sabotage or tampering with the blood. No known instances of sabotage were ever identified.

The growth of the Red Cross national blood program is illustrated by the request from the US Army and the Navy. The first request was for 15,000 pints. In May 1941, when the project had been successful and had convinced key leaders that this could be a successful operation, an additional 209,000 pints were requested. In December 1941 after Pearl Harbor, another 165,000 units were requested. In January 1943, the request for the calendar year was 4 million pints, and the request for the calendar year 1944 was 5 million pints. In November 1941, donations had been approximately 1200 per week, but in December after Pearl Harbor, donations rose to 4000, and by the end of April they exceeded 50,000 per week.

Of the approximately 13 million pints of blood collected by the Red Cross during World War II, 10,299,470 were processed into dried plasma. More than 3 million 200-mL packages were created, and another 2.3 million 500-mL packages. About 310,135 pints of blood were used in military hospitals as either liquid plasma or whole blood. The total cost of the blood donor services to the American Red Cross was approximately $15,870,000, or about $1.19 per pint of blood. Of this amount, about 19 cents was paid from local chapter funds, and the remainder by the national headquarters. (In the original program, the total cost of the operation was born by the Red Cross, but after the project expanded sharply, as of September 1942, the army and navy assumed the cost of servicing the equipment and transporting the blood to processing laboratories.) It was assumed by the government that all funds expended by the Red Cross were contributed by the American people. Despite carefully supervised and appropriate expenditures, it was not possible to estimate what they purchased in terms of human lives saved.

In the beginning of the war, provision of blood was converted almost instantly from a civilian activity with limited scope to one with a major role in the national military effort. It was enormously successful because of the fine organization of the program, the hard work of those who operated it, the hundreds of thousands of hours contributed by volunteer workers, and most of all the voluntary donation of the millions of pints of blood by American citizens, whose gift of themselves saved untold thousands of lives of wounded American troops.

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Note: Much of the information in this chapter was obtained from the Kendrick publication.

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CHAPTER 2

THE CIVILIAN BLOOD SUPPLY AFTER WORLD WAR II

There are two general considerations in the blood supply going forward from the end of the war: 1) the organizations and structure for blood collection and 2) the technology of collection and storage of the blood itself.

The Blood

During the war, ABO typing was standardized and adequate sources of typing sera were arranged. The value of whole blood in treating blood loss, the ability to separate whole blood and prepare plasma and albumin, and the clinical value of whole blood and albumin all were established, as were the means for blood to be stored for 21 days.

At the end of World War II (WWII), it was well understood that whole blood could be anticoagulated with citrate and with dextrose provided as a source of energy. The blood was stored in glass bottles for up to 21 days. Important advances in transfusion medicine science during WWII included understanding the value of plasma in the management of patients with blood loss or patients in shock. The method of plasma fractionation developed by Edwin Cohn, a Harvard biochemist, made it possible to prepare liquid or lyophilized plasma and human albumin. During the war these became the first lines of management of blood loss or shock. The initial work using plasma for transfusion was carried out by John Elliot. Because of the large demand for plasma, Dr. Charles Drew, a New York surgeon, developed the Plasma for Britain program and later established the national structure for the Red Cross to collect thousands of pints of blood.

These became the fundamental basis of the civilian blood supply. But the rather stable situation at the end of the war, with blood being stored in glass bottles for 21 days and plasma being fractionated into albumin or used directly as plasma, was about to undergo drastic change with the development of the plastic bag blood container (see Chapter 3). In the early

days, blood was collected by physicians, but a lack of doctors for this work stimulated a shift to nurses, though with a requirement that a physician had to be in attendance at all times, carrying out physical examinations on donors and available to respond in case of a donor reaction.

The Blood Collection Organizations

At least back to the 1930s, some hospitals collected blood for their own use, but in the 1940s, blood collection locations and organizations were established in local communities to provide blood needed on the battlefield during WWII. During the war, blood had been collected by many hospitals and many blood centers. In 1949-50 in the United States, there were approximately 1500 hospital blood banks, 46 nonhospital blood banks, and 31 Red Cross regional blood centers. Some blood centers continued to operate after the war (see below). Because many hospitals were collecting blood primarily for their own patients, it is unlikely that many discontinued collecting.

The military need for blood decreased substantially after the surrender of Germany in 1945 and dropped to almost none after the surrender of Japan in 1945. Thus, within a short period, the blood needs decreased to just that of the civilian population. The authors were not able to find data on these needs and the collection activities of this period, but there must have been substantial contraction leading to decreased activity and even closure of some blood collection facilities. Some hospitals probably stopped collecting blood because they could obtain it from blood centers that continued to operate but no longer needed to provide blood to the military.

At the end of the war, the Red Cross operated 44 blood centers. Upon the founding of the AABB in 1947, whatever the actual number of locations collecting blood, the situation was very sound at the end of the war period; the national system of blood centers had been established, with well-managed operations and good productivity. The technical aspects of blood collection, storage, and transfusion were established. And the separation of red cells, plasma, and albumin developed and the clinical value of transfusions became well documented.

By 1962, there were 4400 hospital blood banks, 123 nonhospital blood banks, and e American Red Cross regional blood centers, collectively producing 5 to 6 million units of blood per year.

Development of Blood Centers after WWII

After the war, some blood collection organizations continued to collect blood, and others took the initiative to develop new local blood collection capability. In many communities the local American Red Cross took the lead. Thus, from the outset, there was a "market share" dynamic—Red Cross and everyone else—that exists to this day.

Examples of organizations that decided to continue collecting blood and supply it to local hospitals include the Junior League in Milwaukee, the county medical society in San Francisco (Irwin Memorial), the New York Blood Center, the county medical society in Minneapolis (aptly named War Memorial), Hoxworth Blood Center in Cincinnati, Elliott Blood Center in Miami (named for the physician who was key in many wartime activities), and the blood center at the University of Iowa, named after Elmer DeGowin.

The first Red Cross blood center opened in New York in February 1941, collecting plasma. The size of these facilities varied, with weekly collections ranging from 1500 units of blood to 10,500. By January 1944, with the opening of a center in Fort Worth, Texas, there were 44 Red Cross blood centers.

Returning soldiers played an outsized role in building a robust donor population. Better than anyone, they knew from their wartime experience that a reliable blood supply saved lives. Thus, from the late 1940s until well into the 1980s, military veterans contributed disproportionately to communities' blood inventories. In those decades, however, in most locales there was an upper age limit of 65 for donating blood, and these donors' loss of eligibility had a large impact on blood availability, as discussed in Chapter 25.

Suggested Readings

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PART 2

SCIENCE AND TECHNOLOGY

CHAPTER 3

THE PLASTIC BAG AND COMPONENTS

Carl Walter, from Cleveland, Ohio, was recruited to Harvard Medical School by the famous surgeon Elliott Cutler. He also came in contact with another famous physician, Harvey Cushing, so Walter was imbued with an innovative spirit. At that time, in the 1940s, transfusion was performed directly from donor to patient. During one transfusion in the operating room, the tubing broke, splashing blood everywhere, leading Walter to believe there must be a better way. Subsequently he was involved in founding a blood bank at the Brigham Hospital, to avoid the need for direct donor-to-patient transfusion. Space was allocated in a remote basement room because some Harvard trustees believed that it was immoral and unethical to store and use human blood. At first, he used the newly developed anticoagulant citrate in glass bottles, but hemolysis and contamination from air motivated him to develop an airless plastic bag and tubing set. It was rumored that he made the first bags in his kitchen. The bag system was brought to useable form in 1947.

The Plastic Bag Container

In 1949, Walter, with a $2000 investment from an entrepreneurial neighbor, T. Legare Fenn, founded Fenwal Laboratories. “Fen” of Fenwal comes from Mr. T. Legare Fenn. Interestingly, the name is Fenwal and not “Wal-Fen”. Possibly the investment was more important than the technology. Or perhaps “Fenwal” was just more euphonic. Dr. Walter and Mr. Fenn hired a young engineer named David Bellamy, who graduated from Yale in 1949 with a physics degree. Walter and Bellamy selected diethylhexy phthalate (DEHP) for the plastic and used radio frequency to produce the first blood bags.

Walter had developed the first flexible, disposable blood-collection container, which would revolutionize blood banking. In addition to eliminating complications associated with blood collected in glass bottles, such as air embolism, contamination, and breakage, Fenwal’s Blood-Pack system made it possible to separate whole blood into its components through a series of connected disposable containers. This created an industry-wide shift from whole blood transfusion to blood component

therapy, allowing each unit of blood to benefit more patients and allowing physicians to administer only that component of blood needed by the patient.

The new company also developed thermostatic controls for sterilization of surgical instruments, but these controls also ended up in fish tanks, fighter planes, commercial aircraft, and ultimately rockets and missiles. Walter developed automatic ignition systems that replaced pilot lights, and Fenwal had divisions of International Electronics and Controls. He was particularly interested in electrical shock hazards. It is interesting that the man who set the stage for how blood is handled and stored had a large interest in electrical hazards. He retired in 1972. It is not clear when Fenwal divested or closed the parts of the company not involved with plastic blood containers, which became the mainstay of the company and its contribution to blood therapy.

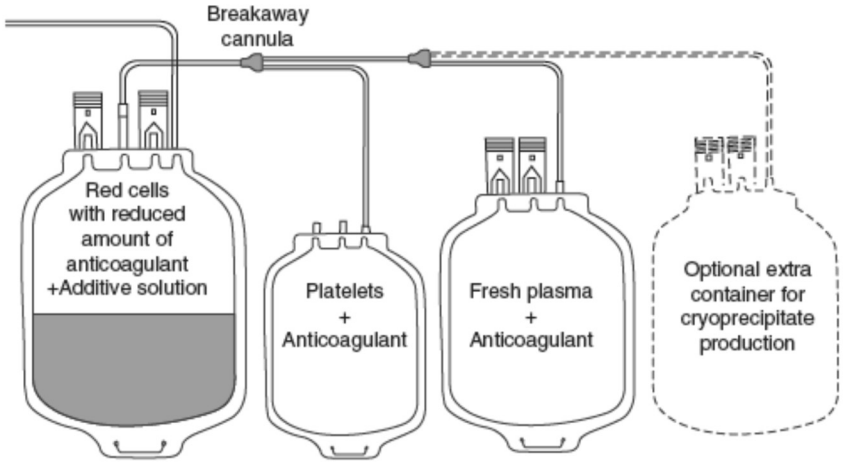

Fig. 3-1. Diagrammatic illustration of the separation of whole blood into red cells, plasma, and platelets.

Over the decades, the plastic bag has been refined in configuration and composition. One of two major advances has been the use of more gas-permeable containers for storage of platelets, providing better cell quality. The other major advance was creating the systems of multiple interconnecting bags, allowing separation of components in a closed system. Thus, a unit of whole blood could be manipulated to produce a unit of red cells, plasma, and platelets, each in its own separate plastic container (Fig 3-1). So, from

blood tubing breaking and spilling blood in the operating room, through the creativity of Carl Walter, David Bellamy, and a few others, we have contemporary blood component therapy.

Components and Component Therapy

The ability to separate whole blood into red cells, plasma, and platelets brought each of these blood "components" into use as individual blood products. Storage as whole blood was not ideal for all the components of whole blood. With separation of whole blood made possible by the plastic bag system, each could be preserved and stored under conditions optimal for that portion of whole blood. Because each blood component had a different composition and characteristic, each had its own unique clinical value. Thus, within just a few years, from each unit of whole blood donated it became possible to produce three different blood products with their different clinical uses.

Blood component therapy was born!

The conversion was not easy, because the whole blood and packed red cell products were different. The red cell unit has a smaller volume. And although a small amount of donor plasma remains, most of the preservative solution is water and electrolytes. Thus, volume-replacement effects are different between the two products.

With this new blood component therapy, whole blood was decreasingly available (a situation now being reconsidered). This led to considerable tension between blood suppliers and transfusing physicians, especially surgeons. The notion developed that "my patient is bleeding whole blood, and that is what I want to replace." This was sometimes followed by the rebuttal, "Is that the way you treat diarrhea in your patients?"

The shift from whole blood to red cells moved ahead, until whole blood was essentially completely replaced. This also meant that single-donor plasma was available. Thus, strategies could be developed to use this to improve hemostasis and for use in trauma and massive blood loss. But far more plasma was available than needed for transfusion. Consequently, this plasma became important raw material for fractionation into plasma derivatives such as albumin, immune globulin, and coagulation factors. The development of platelets prepared from whole blood was more complex. The original method developed at the National Institutes of Health was suitable for small-scale use at that institution and evolved into the current