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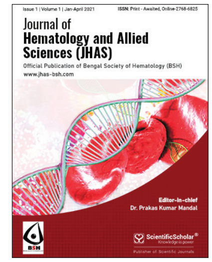

Review Article

Novel aspects in blood transfusion – From donor to patient

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Received: 20 December 2024
Accepted: 01 January 2025
Published: 13 February 2025

DOI
10.25259/JHAS_66_2024

Quick Response Code:

ABSTRACT

Blood transfusion is a critical component of modern healthcare system, which is ensured the availability of safe and compatible blood products for patients as when need. This review article explores the entire journey of blood from donor to patient, emphasizing the importance of voluntary non-remunerated repeat blood donation, rigorous donor selection, and advanced laboratory techniques to ensure transfusion safety. It excavates into the challenges of maintaining an adequate blood supply, the ethical considerations in transfusion practices, and the latest advancements in transfusion medicine. In this article, we discuss the indications for blood transfusion, liberal versus restricted transfusion policies, and the management of transfusion reactions. Through comprehensive analysis and practical insights, main aims of this article to enhance the understanding and implementation of blood transfusion services, ultimately improving patient outcomes.

Keywords: Blood transfusion services, Human immuno-deficiency virus, Transfusion reactions

INTRODUCTION

Blood, blood component, and its product had a long history in medical therapy. From the mid-nineteenth century blood, blood components and its products become a common medical practice globally.[1] During the 18th century Ovidius a Roman poet, pertinent that Princess Medea rejuvenated the aged Prince Aeson by piercing his throat.[2] There was no evidence of blood transfusion by parenterally still seventeenth century; it was given probably by mouth.[3] In the ancient, Rome blood of fallen gladiators was fluttered by men for seeking manhood.[4] At that time, Italian doctors also recommended sucking of blood from youths a forearm vein for rejuvenation.[4] After the discovery of blood group, antigen by Karl Landsteiner in 19th century modern era of blood transfusion was started successfully.[5] From the 2nd World War, huge blood replacement was needed in medical practice.[6] It was also observed that there was increasing blood transfusion hazards, particularly syphilis, hepatitis, along with emergent transfusion related pathogens and hemolytic transfusion reactions.[6] Other serious transfusion hazards also noticed by scientist and medical practitioners such as human error, transfusion related acute lung injury (TRALI), transfusion associated graft versus host disease (TA-GVHD), and transfusion related immune modulation.[7] Sequence of events from a historical perspectives and evolution of blood transfusion practices given in flowchart:

HISTORICAL PERSPECTIVES OF BLOOD TRANSFUSION

Early blood transfusion experiments animal to human (1600) – followed by first successful human to human transfusion by Dr. James Blundell

↓

Discovery of ABO blood group by Karl Landsteiner (1901)

↓

Introduce of blood anticoagulant for blood storage by Mollison (1914)

↓

Development of Blood Bank by Dr. Charles Drew (1940s)

↓

Separation of blood components for various treatment Edwin Cohns (1940s)

↓

Human immunodeficiency virus (HIV) and acquired immunodeficiency syndrome (AIDS) introducing universal precautions (1980s)

↓

Advancement of testing for early detection of viral infection for improvement of blood safety nucleic acid testing introduced (1990s)

↓

Modern innovations started with patient blood management (PBM) strategies along with digital transformation in 2000.

INTERNATIONAL SOCIETY OF BLOOD TRANSFUSION (ISBT) CODE INTRODUCTION AND CODE OF ETHICS

The ISBT Code of Ethics is a set of ethical and professional principles designed to guide the establishment and activities of blood services. It was first developed in 1980 in response to a World Health Assembly resolution calling for the establishment of national blood services and the promotion of voluntary non-remunerated blood donation (VNRBD)1. The code has been periodically reviewed and revised, with the most recent update in 2017.[8,9]

KEY ASPECTS OF THE ISBT CODE OF ETHICS

1. VNRBD: Promotes the health of donors and recipients by encouraging voluntary blood donations without payment
2. Professional standards: Identifies professional standards for those practicing transfusion medicine
3. Ethical principles: Defines ethical principles to underpin the establishment and activities of blood services
4. Health promotion: Focuses on promoting the health of both donors and recipients.

The code is available in multiple languages and serves as a guideline for transfusion medicine professionals worldwide.

Would you like to know more about a specific aspect of the ISBT Code of Ethics or how it is implemented in practice?

NATIONAL BLOOD POLICY

The National Blood Policy in India was adopted in April 2002 by the Government of India to ensure the availability of safe and adequate blood supply.[10] Here are some key points:

1. VNRBD: The policy emphasizes the importance of collecting blood only from voluntary, non-remunerated donors to ensure the safety and adequacy of the blood supply.
2. Blood safety: The policy aims to eliminate transfusion-transmitted infections by implementing rigorous screening and testing protocols for all donated blood.
3. Regulation and oversight: The policy calls for the establishment of regulatory bodies, such as the national blood transfusion council, to oversee and monitor blood transfusion services.
4. Quality management: The policy promotes the implementation of quality management systems and good manufacturing practices in blood banks to ensure the highest standards of blood collection, processing, storage, and distribution.
5. Awareness and education: The policy includes initiatives to raise awareness about the importance of blood donation and to educate the public on safe blood donation practices.
6. Research and development: The policy encourages research and development in transfusion medicine to improve blood transfusion practices and technologies.
7. Elimination of professional blood donation: The policy mandates the removal of professional blood donation to prevent exploitation and ensure the safety of the blood supply.

The National Blood Policy aims to create a sustainable and efficient blood transfusion system that meets the needs of the population while ensuring the highest standards of safety and quality

BLOOD SAFETY VERSUS TRANSFUSION SAFETY

In the early 1980s, there was an epidemic outbreak of HIV/AIDS, had a profound impact on blood safety practices worldwide.[11] World Health Organization (WHO) focused on restructuring and implementation of nationally supported safe and sustainable blood supply systems. In the year 1988, WHO together with the International Red Cross and Red Crescent Society along with World federation of hemophilia decided to initiate a global blood safety initiatives. This led to the implementation of more rigorous screening and testing protocols for blood donations.[12]

In the 20th century, about 80 million units of blood are collected worldwide by the initiatives of local organizers, government institutes, and private hospitals.[13] In the year of 2006, WHO initiates and created blood transfusion services (BTS) protocols (2007) aimed at basic minimum requirements of transfusion for all.[13] There are several novel aspects and advancements in blood transfusion practices that enhance the journey from donor to patient. The key concept of transfusion safety versus blood safety was coined by European commission Directives 2002/98/CE.[13] They refer that transfusion related to all activities "closed to the patient's side" and blood safety associated with "task carried out by blood service."[13]

Author Seghatchian J in 2019 in the Journal of Transfusion and Apheresis Science mentioned that practice of blood safety and transfusion safety are linked by "six Ps" - Six "P"s are as follows: - (i). People, (ii). Procurement, (iii). Process/Procedures, (iv). Patients, (v). Price containment, and (vi). Policies.

SOME KEY DEVELOPMENT OF BLOOD TRANSFUSION SERVICES

There are numerous evaluations and innovations of transfusion medicine into clinical oriented discipline emphasizing donor to patient care has been accompanied by challenges. To overcome the challenges and emerging issues, currently various measures taken for safe blood transfusion. They are as follows: such as machine learning, microfluidics devices, and robotics are being integrated into transfusion medicine to improve accuracy and efficiency.

Technological advancements

Blockchain technology

Blockchain ensures secure and transparent documentation of the entire blood transfusion process, from donation to patient. It helps in tracking and verifying the journey of blood products, reducing errors and enhancing traceability.[14,15]

Internet of things (IoT)

IoT devices monitor the storage conditions of blood, such as temperature and humidity, ensuring that blood products are kept in optimal conditions throughout the supply chain.[16,17]

Machine learning and artificial intelligence (AI)

These technologies optimize donation intervals for individual donors, predict blood demand, and manage blood inventory more efficiently. They also help in identifying potential donors and improving the matching process between donors and recipients.[18]

Microfluidics devices

These devices allow for precise and automated handling of small volumes of blood, improving the efficiency and accuracy of blood testing and component separation.[19,20]

Robotics

Automated systems and robotics are used for blood collection, processing, and testing, reducing human error and increasing throughput.[21,22]

Augmented reality (AR)

AR technology helps medical professionals locate veins more accurately during blood donations, making the process less painful and more efficient for donors.[23,24]

Non-invasive hemoglobin screening

This technology allows for quick and painless measurement of hemoglobin levels, ensuring that donors are healthy and eligible to donate blood.[25-27]

Digital transformation

Technologies such as blockchain, AI, and the IoT are being used to enhance traceability, reduce errors, and manage blood supply more effectively.

Blockchain technology

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AI and machine learning

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Radio-frequency identification (RFID)

RFID tags are used to track blood products throughout the supply chain, ensuring accurate and efficient management of blood inventory.[31]

E-RaktKosh

This is a pioneering digital initiative by the Government of India to revolutionize blood banking. It creates a centralized blood inventory, streamlines the donation process, and enhances transparency and efficiency in blood management.[32]

PBM

This approach focuses on optimizing the use of blood products, minimizing transfusions, and improving patient outcomes through better management strategies.[33]

Donor management

Ensuring that blood donors are healthy and eligible to donate, minimizing the risk of adverse reactions and improving the quality of donated blood.[34]

Blood collection and processing

Using advanced technologies to collect, test, and process blood efficiently, ensuring that blood products are safe and effective.[35]

Storage and distribution

Monitoring and maintaining optimal storage conditions for blood products, using technologies like IoT to track and manage inventory.[36]

Patient evaluation

Assessing patients' medical and surgical needs to determine the necessity of a transfusion, considering alternatives to transfusion when possible.[34]

Minimizing blood loss

Implementing strategies to reduce blood loss during surgeries and medical procedures, such as using minimally invasive techniques and optimizing hemostasis.[37,38]

Treating anemia

Addressing anemia in patients through appropriate medical management, including iron supplementation and other therapies, to reduce the need for transfusions.[39]

Transfusion decision-making

Making informed decisions about transfusions based on clinical evidence and patient-specific factors, ensuring that transfusions are used judiciously.[34]

Post-transfusion care

Monitoring patients after transfusions to detect and manage any adverse reactions or complications.[40]

Hemovigilance

Enhanced monitoring and reporting systems are in place to ensure the safety and quality of blood transfusions, reducing the risk of transfusion reactions and other complications. Hemovigilance is a comprehensive system of surveillance procedures that monitor the entire transfusion chain, from blood donation to patient follow-up.[41-43] Here's how it works from donor to patient:

Donor screening and selection

Ensuring that donors are healthy and eligible to donate blood, minimizing the risk of adverse reactions and improving the quality of donated blood.

Blood collection and processing

Using advanced techniques to collect, test, and process blood efficiently, ensuring that blood products are safe and effective.

Storage and distribution

Monitoring and maintaining optimal storage conditions for blood products, using technologies like IoT to track and manage inventory.

Transfusion to patients

Administering blood products to patients while monitoring for any adverse reactions or complications.

Follow-Up

Continuously tracking patients after transfusion to detect and manage any adverse reactions or complications, ensuring their safety and well-being.

Hemovigilance programs, such as the Hemovigilance Program of India, collect and analyze data on adverse reactions to improve blood transfusion practices and prevent their recurrence. This system helps identify potential hazards, triggers corrective actions, and enhances the overall quality and safety of blood products and the transfusion process.

Directed donation

Modern practices include considerations for directed donations, where blood is donated specifically for a known recipient, under certain conditions. Directed donation is when a specific donor, often a family member or friend, donates blood specifically for a particular patient.[44-46] Here's how it works from donor to patient:

Request

The patient's physician submits a request for a directed donation, specifying the patient's blood type and any other relevant information.

Donor screening

Potential donors are contacted and screened to ensure they meet all eligibility criteria for blood donation.

Blood collection

The selected donors make their blood donations at designated collection centers.

Processing and testing

The donated blood is tested and processed to ensure it is safe for transfusion.

Transfusion

The blood is then made available for the patient's transfusion, typically within a few days to a week.

While directed donations can provide a sense of security for patients and their families, it is important to note that all donated blood undergoes the same rigorous testing for infectious diseases, ensuring the safety of the blood supply

Non-immune reactions

Efforts are being made to better understand and manage non-immune transfusion reactions, which can occur due to factors other than immune responses. Non-immune reactions in blood transfusions are adverse events that occur without the involvement of the immune system.[47,48] These reactions can still pose significant risks to patients. Here are some common non-immune reactions:

Febrile non-hemolytic transfusion reactions

These are characterized by fever and chills during or shortly after a transfusion. They are often caused by cytokines released from leukocytes in the stored blood.

Allergic reactions

These can range from mild (itching, hives) to severe (anaphylaxis). They are usually caused by allergens present in the transfused blood products.

Transfusion-associated circulatory overload

This occurs when the volume of blood transfused is too much for the patient's circulatory system to handle, leading to symptoms such as shortness of breath, hypertension, and pulmonary edema.

TRALI

This is a serious condition where the lungs become inflamed and fill with fluid, leading to respiratory distress. It is thought to be caused by antibodies in the donor blood reacting with the recipient's leukocytes.

Hemolysis

Non-immune hemolysis can occur due to physical damage to red blood cells (RBCs), such as incorrect storage conditions, using the wrong gauge needle, or bacterial contamination of blood products.

These reactions highlight the importance of careful monitoring and management during and after blood transfusions to ensure patient safety.

Future perspectives

Human umbilical cord blood is a valuable source of hematopoietic stem cells, which can develop into all three types of blood cells: RBCs, white blood cells, and platelets. This makes it a promising option for the correction of anemia.

Hematopoietic stem cells

Umbilical cord blood contains a rich supply of these stem cells, which have the potential to reconstitute an individual's entire blood supply.

Clinical applications

Cord blood has been used successfully in treating various blood and immune disorders, including anemia. It has been particularly beneficial for patients with conditions like Fanconi anemia.[49,50]

Advantages

Compared to traditional bone marrow transplants, cord blood transplants have a lower risk of GVHD and do not require as strict a match between donor and recipient.

Research and development

Ongoing research continues to explore the full potential of cord blood in treating anemia and other blood disorders.

Advancement of cellular therapy and regenerative medicine

Culture RBCs. Culturing RBCs *in vitro* is a promising approach to address blood shortages and improve transfusion safety.[51-53] Here are some key points about the process:

Source of cells

RBCs can be cultured from various sources, including adult peripheral blood, umbilical cord blood, and induced pluripotent stem cells.

Culture systems

Advanced culture systems have been developed to efficiently differentiate erythroid cells (precursors to RBCs) from these sources. These systems often involve multiple stages and can achieve significant expansion of erythroid cells.

Enucleation

A critical step in RBC culture is the enucleation process, where the nucleus is removed from the developing erythroid cells to produce mature, functional RBCs.

Quality control

The cultured RBCs are rigorously tested to ensure they meet the necessary quality standards, including deformability, oxygen-binding capacity, and compatibility with blood group antigens.

Clinical applications

Cultured RBCs have potential applications in transfusion medicine, particularly for patients with chronic conditions requiring regular transfusions, such as sickle cell disease and thalassemia.

Safety

Cultured RBCs offer advantages over donor-derived blood, such as reduced risk of infectious disease transmission and alloimmunization (immune response against transfused blood

New developments of human blood cells

Artificial blood, also known as blood, substitutes, aims to mimic and fulfill some functions of biological blood.[54,55]

Types of blood substitutes

The main categories of oxygen-carrying blood substitutes being pursued are hemoglobin-based oxygen carriers (HBOCs) and perfluorocarbon emulsions. HBOCs use modified human or bovine hemoglobin to transport oxygen, while perfluorocarbon emulsions are synthetic compounds that can carry and release oxygen.[56]

Advantages

Artificial blood can potentially address blood shortages, reduce the risk of disease transmission, and eliminate the need for blood type matching. It can also be stored at room temperature and has a longer shelf life compared to donated blood.

Challenges

Despite significant research, there are no Food and Drug Administration-approved oxygen-carrying blood substitutes commercially available yet. Early attempts faced significant side effects, and safety concerns have led to the discontinuation of some clinical trials.

Current use

While fully functional artificial blood is not yet available, non-blood volume expanders like saline solutions are used to maintain blood pressure and volume in emergency situations.[57]

Prospects

Ongoing research aims to develop safe and effective blood substitutes that can be used in clinical settings, especially in emergency situations and areas with limited access to donor blood.

CONCLUSION

The future blood transfusion holds exciting prospects driven from donor selection process to technological advancements which give an innovative service to patients care. Some key area for safe blood transfusion are widespread strategies in PBM, digital transformation, artificial blood substitutes, and advance cell therapies. This ongoing effort enhances the safety, availability, and effectiveness of blood transfusion services in health care system.

Acknowledgments: This review article based on selected national and international journal articles. The author is thankful to all staffs and postgraduate trainee, senior residence of Department of IHBT, Medical College, Kolkata. I am also thankful to SBTC personal and special thanks to Dr. Barun Santra (JDBS) and Dr. Abhijit Mandal (AD-Medical) for their conceptual support.

Ethical approval: Institutional Review Board approval is not required.

Declaration of patient consent: Patient's consent was not required as there are no patients in this study.

Financial support and sponsorship: Nil.

Conflicts of interest: There are no conflicts of interest.

Use of AI-assisted technology for manuscript preparation: The authors confirm that there was no use of AI-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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How to cite this article: Talukdar B, Bhattacharya P. Novel aspects in blood transfusion – From donor to patient. J Hematol Allied Sci. 2025;5:18-25. doi: 10.25259/JHAS_66_2024