Revolutionizing Blood Bank Management with Ai: Smart Solutions for Life-Saving Efficiency

Ms. Seema B. Kharwade[1], Ms. Ishika P. Bansod[2]
[1]*Assistant Professor, Department of Pharmaceutical Quality Assurance, P. R. Pote Patil College of Pharmacy, Amravati, 444604 (Maharashtra)*
[2]*B. Pharma student, P. R. Pote Patil College of Pharmacy, Amravati, 444604 (Maharashtra)*

***Abstract*—Blood is a non-replenishable entity, the only source of that are people. well timed availability of great blood is a crucial requirement for sustaining the healthcare offerings. consequently, keeping quality of blood and identification of expert Donors is a prime obligation of blood banks. The green control of blood donation and transfusion stays an important difficulty in cutting-edge healthcare. Conventional blood financial institution structures regularly face challenges which include donor scarcity, wastage, mismanagement and shortage of actual-time traceability. E-Bloodline, a conceptual framework integrating synthetic Intelligence (AI), system learning (ML) and Blockchain, goals to revolutionize blood financial institution operations. This evaluation discusses how E-Bloodline can allow actual-time donor profiling, blood stock prediction, smart scheduling and at ease digital traceability the use of decentralized technology. the mixing of AI permits for demand forecasting and most beneficial usage of assets, while Blockchain ensures statistics safety, transparency, and tamper-evidence donor-recipient information assist the potential of smart platforms in lowering blood wastage and enhancing healthcare shipping. The adoption of E-Bloodline-like systems should extensively beautify the availability, safety and efficiency of blood transfusion services, particularly in useful resource-constrained settings. Further research is suggested to discover actual-global implementation challenges, consisting of statistics privateness, machine interoperability and moral issues.**

***Index Terms*—Artificial Intelligence (AI), Blockchain Technology, E-Bloodline System, Blood Bank Management, Internet of Things, Predictive Analytics.**

I. INTRODUCTION:

Blood

Blood is a fluid connective tissue derived from mesoderm. It a mesenchymal tissue. Blood flows thru a capillary are described with the aid. It circulates constantly across the body, propelled through the pumping motion of the heart [32,33]. It transports dissolved gases which includes oxygen, nutrients, hormones, heat, antibodies and cells of the immune machine, plasma proteins, which includes clotting factors, drugs and wastes. Blood consists of a clear, straw coloured watery fluid referred to as plasma, in which several extraordinary styles of blood cellular are suspended [32,33]. Plasma usually constitutes 55% of extent of blood and the mobile fraction 45%. Blood makes up about 7% of frame weight (approximately 5.6 litres in a 70 kg mam). This share is less in women and considerably more in kids, progressively reducing till the adult level is reached. the overall quantity in adults is set 80ml/kg body weight in males and 70ml/kg in ladies. Blood never stops shifting within the blood vessels and the continuing blood flow maintains reasonably consistent surroundings for frame cells, controlling key factors including water distribution and the pH of body fluids. The blood additionally facilitates to maintain middle frame temperature by means of distributing warmth produced with the aid of metabolically energetic organs, together with operating skeletal muscle tissues and liver, across the frame [32,33].

Blood groups

Early tries to transfuse blood from one character to another or from animals to human had been simplest not often successful, the recipient of the blood typically turning into very sick or death. It’s miles now acknowledged that the erythrocyte membrane companies a variety of different proteins (antigens) which can stimulate an immune response if transferred from one character (the donor) into the bloodstream of an incompatible recipient, these antigens, that are inherited from the mother and father, determine the character's blood group [32,33]. If a recipient is transfused with the blood of the identical organization, i.e., owing the equal name surface antigens, their immune system will now not realize them as an overseas antigen and break the transfused cells, that is the premise the idea of the transfusion reaction: the blood sorts, the donor and the recipient are incompatible. There are many special collections of red cellular surface antigens, but the most vital are the ABO and the Rhesus system [32,33]. The characteristics of different blood groups, including their antigens, antibodies and compatibility are summarized in Table 1.1.

1) The ABO system

About 55% of the United Kingdom population has either antigen A (blood group A), antigen B (blood group B), or both (blood organization AB) on their crimson cell surface. The remaining 45% have either A nor B antigens (blood organization O). Antibodies to these antigens are called anti-A antibodies and anti-B antibodies respectively. Blood institution A individuals can't make anti-A antibodies, since in any other case a response to their own cells might occur, they are able to however make anti-B antibodies, because the B antigens non self and overseas. Blood organization B people, for the identical purpose, could make simplest anti-A antibodies. Blood institution AB makes either antibody and blood institution O makes anti-A and anti-B antibodies, they're occasionally referred to as common recipients: transfusion of either kind A or kind B blood into these people is probable to be secure, for the reason that there aren't any antibodies to react with them. Conversely institution O humans have neither A nor B antigens on their pink cell membranes, and their blood may also normally be appropriately transfused into A, B, AB or O types: group O is occasionally known as the well-known donor and recipient relationships of ABO groups are shown in Fig 1.1.

2) The Rhesus system

The erythrocyte membrane antigen critical here is the Rhesus (Rh) antigen, or Rhesus aspect, on occasion additionally known as the D antigen, approximately 85% of people have this antigen; they're Rhesus tremendous (Rh+) and do no longer consequently make anti-Rhesus antibodies. The remaining 15% don't have any Rhesus antigen (they may be Rhesus-terrible, or Rh-). Rh- individuals will produce anti-Rhesus antigen but this typically occurs handiest in sure occasions, e.g., in being pregnant or because the end result of an incompatible blood transfusion.

Table 1.1: Blood Groups-Antigens, Antibodies, Donor and Recipient Compatibility

Sr. No.	Blood group	Antigen	Antibodies	Donor	Recipient
1	A	Antigen A	Anti-b	A and AB	A and O
2.	B	Antigen B	Anti-a	B and AB	B and O
3	AB	Antigens A and B	Neither anti-a nor anti-b	AB only	Universal Recipient
4	O	Neither a nor B antigen	Both anti-a and anti-b	Universal Donor	O only

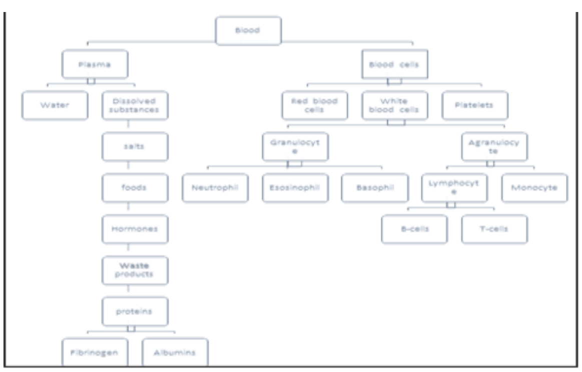

Fig.1.1: Composition of blood Components.

Blood donation

Blood donation is vital to all of transfusion remedy, because it presents the beginning product. In economically advanced countries, all of the blood is given via volunteer, nonremunerated donors [10,37]. Donated whole blood is then made into transfusable components, which consist of however aren't limited to packed purple blood cells (RBCs), platelets and frozen plasma or cryoprecipitate [10,37]. Other lesser utilized blood components, which includes granulocytes and cryoprecipitate-depleted plasma, also have essential healing price. Character plasma proteins, such as issue VIII, had been manufactured the use of recombinant techniques for years; however, there is no commercial product, single or mixed, with the scientific homes of frozen plasma.

1. The process of blood donation

Blood donation may be divided into five procedures which might be without delay associated with the donor: recruitment, screening, physical exam, series, and publish donation care, as depicted in Fig. 1.2. Recruitment of blood donors is a specialized project. It's miles often carried out by means of telerecruiters, and the message delivered must be convincing and compelling to bring about a scheduled appointment to donate blood [10,37]. As soon as a donor has been recruited, the screening system is carried out to ensure that the donation technique might be secure for the donor and that the accumulated blood may be safe for the recipient. The potential donor is to begin with given facts approximately the method itself. The screening procedure includes a questionnaire that seeks to find medical situations and behaviours that might makes donation dangerous for the donor or recipient. Vital information is confirmed by means of direct verbal thinking to make sure that the solutions are correct. If no disqualifying records is exposed in the course of the screening method, a short physical examination follows, which incorporated examination of antecubital veins, followed with the aid of size of body temperature, donor haematocrit or haemoglobin and coronary heart rate. After the venipuncture is completed, blood is massed, labelled and temporarily saved until it is able to be transferred to a production centre for in addition processing and distribution. Specimen tubes are drawn at the time of series for infectious disease checking out; these tubes are sent for checking out right away after collection. After the donation, donors get hold of oral fluids and stay below commentary for a time frame so that any submit donation reactions may be treated correctly. Post donation instructions are given to assist the donor avoid untoward side consequences. The donor is advised to call the blood centre with any publish donation information, consisting of the development of worrisome bodily signs or information remembered that might exchange the answers given all through the screening technique.

2. Blood purification techniques

Blood purification techniques represent a diverse group of methods designed to remove unwanted cells, pathogens, toxins, or plasma constituents from the blood, thereby improving its safety for transfusion or its therapeutic use in clinical practice. In blood banks, these techniques—such as leukoreduction, irradiation, pathogen inactivation, and washing of red cells—are primarily employed to enhance the quality of stored blood and prevent transfusion-related complications [19,23,31] are illustrated in Fig.1.3. Beyond the blood bank, advanced extracorporeal purification procedures, including centrifugation, filtration, cascade filtration, adsorption methods, hemoperfusion, photopheresis, and cytapheresis, have evolved as vital therapeutic interventions for conditions ranging from autoimmune diseases to intoxications [23,27]. Together, these approaches highlight the growing role of technology in ensuring both the safety of blood products and the therapeutic potential of blood purification.

Fig. 1.2: process of blood donation

A) At blood banks

Those are general techniques finished in blood banks to improve the safety and quality of blood for transfusion:

a) Leukoreduction (Leukodepletion)- removal of white blood cells by unique filters to prevent febrile reactions, alloimmunization and CMV transmission.

b) Irradiation-Exposure of blood components to gamma/X-rays to inactive donor lymphocytes and prevent transfusion-associated graft-versus-host disease (TA-GVHD).

c) Pathogen Inactivation-Use of chemicals/UV light (e.g., riboflavin, methylene blue) to inactivate viruses, bacteria and parasites.

d) Washing of Red Blood Cells-Removal of plasma proteins and antibodies with saline; used in patients with allergic reactions or IgA deficiency.

e) Cryopreservation-Long-term preservation of rare blood units using cryoprotectants (like glycerol).

f) Plasma Fractionation-Separation of plasma into therapeutic components such as albumin, clotting factors and immunoglobulins.

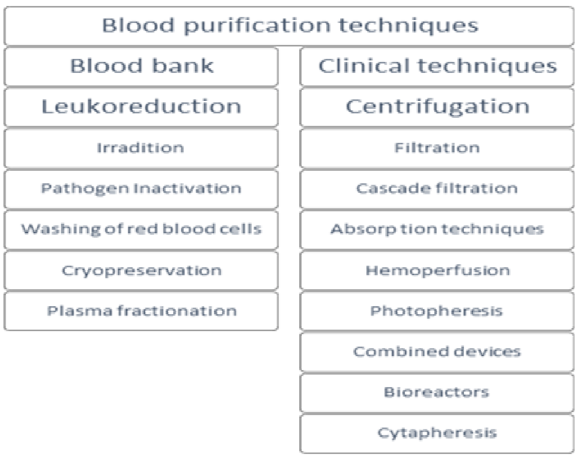

Fig. 1.3: Blood Purification Techniques

B) At clinical

a) Used in therapeutic apheresis units and extracorporeal blood purification, but can be cited as “extended blood purification” methods.

b) Centrifugation-Separation of blood components by density using centrifugal force (basis of apheresis, also used in blood banks).

c) Filtration-Removal of unwanted particles or cells by passing blood through specific pore-size filters (e.g., leukocyte filters, microaggregate filters).

d) Cascade Filtration (Double Filtration Plasmapheresis)-Plasma is filtered twice: first to separate plasma, then to selectively remove large molecules (autoantibodies, immune complexes).

e) Adsorption Techniques-Use of adsorbent columns coated with antibodies, proteins, or resins to selectively remove toxins, antibodies, or lipoproteins from blood.

f) Hemoperfusion-Passing blood through a cartridge containing activated charcoal or resins to remove toxins, drugs, or cytokines (used in poisoning, sepsis).

g) Photopheresis (Extracorporeal Photo chemotherapy).

h) Affected person’s leukocytes are treated with a photoactive drug (e.g., eight-MOP) and exposed to UV mild before reinfusion; beneficial in cutaneous T-cellular lymphoma, GVHD, autoimmune diseases.

i) Combined Devices-Integration of multiple purification methods (e.g., hemoperfusion + dialysis, filtration + adsorption) for broader toxin removal.

j) Bioreactors-Experimental devices using living cells or enzymes to metabolize toxins and improve blood detoxification (future potential in artificial liver/kidney support).

k) Cytapheresis-Selective removal of cellular components (leukapheresis, plateletpheresis, erythrocytapheresis) for therapeutic or donation purposes.

II. IMPORTANCE

This project serves as a digital repository of blood-related information, enabling emergency and location wise access. It ensures easy accessibility, storage and seamless sharing of data among healthcare providers, blood banks and hospitals. By harnessing the power of artificial intelligence (AI) and modern digital technologies, the system aims to provide real-time monitoring predictive analysis and effective management of blood supply and demand. This not only guarantees accurate and timely responses in emergency situations but also helps in optimizing resource utilization, reducing wastage and improving patient outcomes through a more reliable and transparent manner.

III. CONVENTIONAL METHODS

Standards for blood banks: the acceptance of blood:

Blood banks follow strict eligibility criteria to ensure the safety of both the donor and the recipient [2, 35]. These standards are designed to maintain the quality of donated blood, prevent the transmission of infectious diseases, and protect donors from any health risks associated with blood donation. The criteria generally cover donor age, weight, haemoglobin levels, vital signs, donation intervals, medical history, lifestyle factors, and mandatory screening for transfusion-transmissible infections are represented in Fig.1.4. Only when these conditions are satisfactorily met, the donated blood is accepted for clinical use.

Criteria for protection of donor

- General Appearance
- Drug therapy
- Donation Interval
- Age
- Hemoglobin
- Pulse
- Donar weight

Criteria for protection of the recipient

- General Appearance
- Temperature
- Immunizations and vaccinations
- Dnor skin
- Receipt of blood or blood components
- infectious diseases
- Alcohol, Narcotics
- Aspirin Ingestion
- AIDS

Fig 1.4: standards for Donor and Recipient Eligibility in Blood Banks

(1) CRITERIA FOR PROTECTION OF THE DONOR

At the day of donation, the potential donor's records shall be evaluated and the donor tested through a certainly certified individual trained to make use of the subsequent suggestions so as to determine that the blood donation will not be destructive to the donor.

1. General

Potential donors with sickness of the heart, liver or lungs or with a history of most cancers, ordinary bleeding tendency or convulsions after infancy, will be excluded situation to assessment with the aid of a qualified medical doctor.

2. Drug therapy

Drug therapy, including antibiotics, may indicate that blood donation will be deleterious to the donor or to the recipient; therefore, the scientific indication for such remedy should be decided.

3. Donation Interval

Except for reasonable qualifying instances, the programming language between donations for a full unit of blood shall be as a minimum 8 weeks complete blood donation have to be deferred for as a minimum forty-eight hours after hemapheresis.

4. Age

Blood donors shall be between the ages of 17 years through sixty-five years with the following exceptions:

Potential donors who're considered minors beneath relevant law may be common handiest if written consent to donate blood has been acquired in accord with relevant regulation. After the 66th birthday, potential donors can be ordinary at the discretion of a blood bank medical doctor [2].

5. Haemoglobin or packed cell volume (Hematocrit)

The hemoglobin attention or packed cell quantity will be determined with a pattern of blood acquired by way of capillary puncture or phlebotomy. The hemoglobin shall be no less than 12.5 g/dl for prospective female donors, and no less than 13.5 g/dl for prospective male donors. The packed cell volume, if substituted, shall be no less than 38% for ladies, and no less than 41% for guys.

6. Pulse

The heartbeat shall display no pathological cardiac irregularity and ought to be between 50 and one hundred beats consistent with minute. If a potential donor is an athlete with high workout tolerance, a lower pulse charge can be proper.

7. Donor weight

Donors weighing 50 kg or greater mostly may also provide 450+45ml or 450-50ml of blood, further to pilot samples which shall no longer exceed 30ml. donors weighing much less than 50kg can be bleed proportionately less in a reduced volume of anticoagulant.

(2) CRITERIA FOR PROTECTION OF THE RECIPIENT

On the day of donation, the potential donor's records will be evaluated and the donor tested by using a suitably certified character educated to utilize the following guidelines to exclude the donor with proof of disease transmissible via blood transfusion.

1. General appearance

The individual being considered as a donor must appear physically fit and free from obvious illness.

2. Temperature
The acceptable upper limit for oral temperature is 37.5 degree Celsius.

3. Immunizations and vaccinations
Men and women recently immunized with toxoids and killed virus, bacterial and rickettsial vaccines are desirable if they are symptom unaffected and afebrile. These consist of vaccines towards hepatitis B, diphtheria, pertussis, typhoid, paratyphoid, cholera, typhus, Rocky Mountain spotted fever, influenza, polio and plague.
After vaccination for smallpox, donors are acceptable while the scab has fallen off or 2 weeks after an immune response. Following inoculation with attenuated virus vaccines along with polio (oral), measles (rubeola), mumps or yellow fever, donors are deferred for 2 weeks; following inoculation for German measles (rubella, deferral is for four weeks. Potential donors will be deferred for twelve months after receiving Hepatitis B immune Globulin (HBIG).

4. Donor skin
The venipuncture site should be clear of any cuts, sores or skin abnormalities.

5. Receipt of blood or blood components.
Prospective donors who during the preceding 6 months have received blood, or those humans blood components known to be possible source of hepatitis shall be excluded.

6. Infectious diseases
A potential donor will be unfastened from infectious sickness regarded to be transmissible by way of blood insofar as can be decided through traditional examinations and records.
• Viral hepatitis-
potential donors shall be disqualified completely for 1) a history of viral hepatitis, 2) a history of a reactive check for hepatitis B floor antigen (HBsAg), or 3) donation of the most effective unit of blood or blood component transfused to a affected person who within 6 months advanced posttransfusion hepatitis and who received no different blood derivative known to transmit viral hepatitis and there has been no other in all likelihood supply of contamination.

• Malaria-
tourists who're everlasting residents of nonendemic nations but who've been is a place taken into consideration endemic for malaria by means of the Malaria branch, Centres for disease control, US department of fitness and human services, can be typical as ordinary blood donors 6 months after return to the nonendemic location, presenting they were freed from unexplained febrile illness and have now not taken antimalarial tablets [2,35].

a) Alcohol, Narcotics
Apparent stigmata of narcotic or alcoholic habituation or intoxication shall exclude a prospective donor. Both palms need to be inspected for proof of repeated venipunctures.

b) Aspirin Ingestion
Ingestion of aspirin containing medical drug inside three days of donation need to ward off use of donor as the only supply of platelet preparations for a recipient.

c)Acquired immune deficiency syndrome (AIDS)
All donors should be given academic materials informing them of the excessive-hazard corporations for AIDS and that individuals in those agencies have to refrain from donating blood. Donor screening needs to consist of questions referring to signs and signs and symptoms of AIDS and Kaposi's sarcoma.

IV. INNOVATIVE APPLICATIONS OF AI

(1) Plan of work
E-Blood financial institution is an integrated blood bank automation device which inter-connects all the blood banks of the country into unmarried network [17,29]. It manages all sports beginning from blood series to trouble to blood devices to sufferers. The device also maintains record on voluntary donors, alternative donors and many others with signal and acknowledgement mechanism for donors and blood bank users [17,35] This is a powerful management device for both man or woman blood banks and banks managed through government through interconnecting all into an unmarried network.
The E-Blood bank tracking machine represents an innovative approach to modernizing the management and distribution of blood and blood merchandise.

Conventional blood financial institution operations face widespread demanding situations, together with inefficient inventory management, terrible traceability, restrained accessibility to actual time information and difficulties in preserving a responsive donor base. This study explores the development and implementation of an E-Blood financial institution tracking device that leverages advanced technologies inclusive of the internet of things (IoT), blockchain and internet/cellular packages to cope with these troubles [13,15]. The primary goal of the E-Blood financial institution operations by means of integrating contemporary technology. Especially the system targets to enhance inventory control via actual time monitoring of blood gadgets, make certain give up to give up to information on blood availability. Additionally, it seeks to optimize donor management to hold an active donor base, make sure the excellent and safety of blood through IoT-monitored garage situations and facilitate short responses to pressing blood needs. Blood financial institutions refer to the method of checking out, collecting, keeping apart and storing blood. It’s far virtually hard for them to touch different people to acquire blood in a quick time that is the primary trouble we want to resolve via our utility.

Our utility serves as a digital repository for any emergency or region wise cases; ensuring smooth accessibility and sharing through harnessing the strength of AI, our devices seek to ensure to extra correct and timely response to blood supply call for. This mission isn’t always only a tech innovation- it’s lifesaving initiative with actual global impact and strong enterprise potential. The conceptual workflow of an AI and blockchain based blood bank system is shown in Fig.1.5.

(2) Methods of monitoring

Supervision is essential for maintaining the security, dependability and smooth functioning of the e-Blood Bank. Advanced methods are employed to oversee and record each step involved in blood donation, reservation and supply:

- Real-Time Environmental Monitoring: IoT- based sensors provide live monitoring of storage temperature, humidity, and quality conditions of blood units. Any deviation from the standard range triggers alerts to maintain safety.
- RFID and Barcode Tracking: Each blood bag is labelled with RFID/barcodes, ensuring end-to-end traceability from donor to recipient and reducing handling errors [24,29].
- AI-Based Predictive Analytics: Artificial intelligence models analyse past data to forecast demand and supply trends, helping to reduce wastage and prevent shortages.
- Blockchain Integration: Blockchain technology provides tamper-proof records of donations, testing, and transfusion, ensuring transparency and accountability.
- Dashboards and Alerts: Centralized dashboards display real-time inventory levels and expiry dates, while automated SMS, email, or app notifications ensure rapid response in emergencies.

(3) Comparison of traditional blood bank and AI-based e-blood bank system.

Blood banks have always played a vital role in healthcare, but conventional systems are often limited by manual processes, delayed communication, and lack of transparency [10,35,37]. These shortcomings not only affect the efficiency of blood collection and storage but also create challenges in responding quickly to emergencies. In many cases, delays in finding the right blood group or errors in inventory management can cost precious lives.

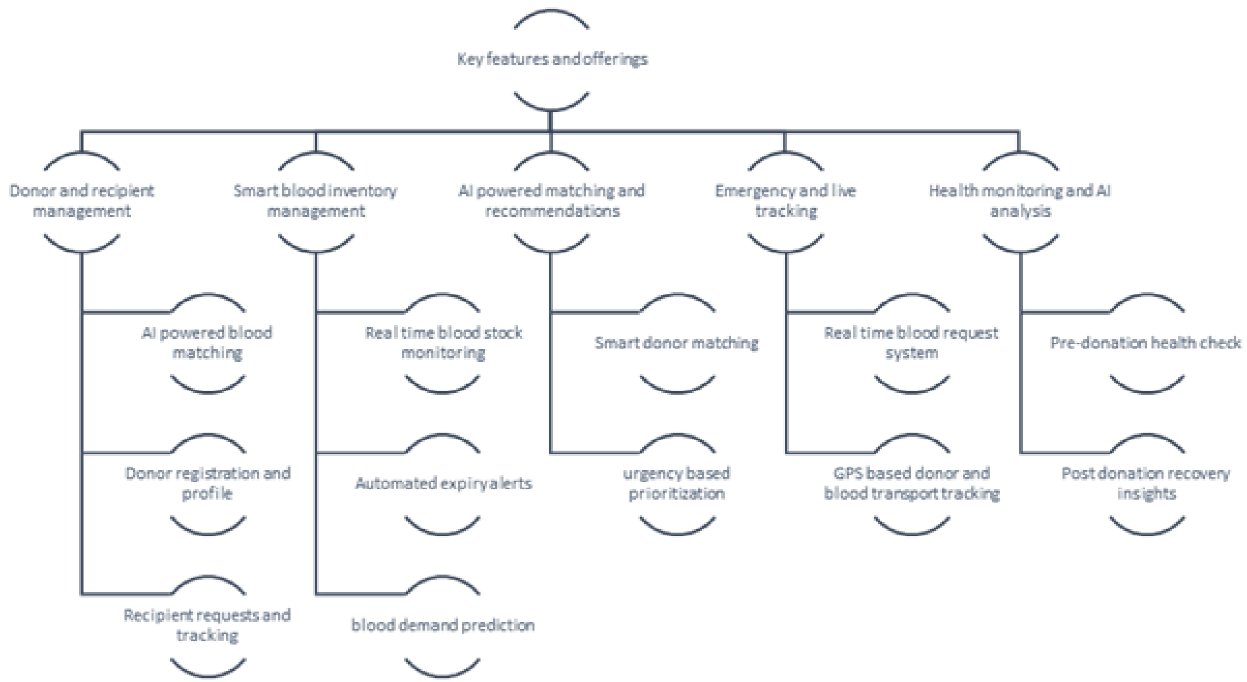

Fig. 1.5: Conceptual Model of AI-Based Blood Bank Management

By incorporating Artificial Intelligence (AI), Blockchain, and IoT, e-Blood Bank systems offer a smarter and more reliable approach [17,29]. (Fig.1.5) They not only address the inefficiencies of traditional methods but also introduce advanced features such as predictive analytics, real-time monitoring, and tamper-proof record-keeping. By doing so, they enhance safety, transparency, and accessibility across the entire blood management chain. The following Table 1.2. provides a side-by-side comparison between the limitations of traditional blood bank practices and the innovations brought by AI-driven e-Blood Bank systems:

Table 1.2: Comparison of Traditional vs AI-Based Blood Bank System

Feature	Traditional blood bank	AI based e-blood bank system
Inventory management	Manual record keeping, prone to error and delays.	AI driven forecasting ensures optimal stock levels and reduces wastage.
Donor recruitment and retention	Relies on manual calls and awareness camps	Automated reminders. NLP-based communication and predictive donor profiling improve retention.
Traceability	Limited tracking risk of mismatch and data loss	RFID/ blockchain ensures end to end tamper proof traceability
Data accessibility	Restricted to individual banks, slow in emergencies.	Real time dashboards accessible across a digital network
Safety monitoring	Periodic manual checks of storage conditions	IoT sensors provide continuous real time monitoring with instant alerts.
Transparency and trust	Records vulnerable to manipulation or errors	Blockchain secured records increase transparency and trust
Emergency response	Delays in locating required blood groups	AI enabled quick matching and immediate availability through connected networks.
Scalability	Limited to local or regional operations	Nationwide/ global interconnection possible with digital integration.

Advantages

1. Improved Forecasting of Blood Demand: AI-driven predictive models allowed accurate estimation of blood requirements, which helped prevent shortages and ensured optimal inventory levels [17,24].
2. Reduction in Wastage of Expired Units: Smart algorithms and IoT-enabled monitoring reduced the number of expired blood units by tracking shelf life and providing early alerts for redistribution [15,35].
3. Enhanced Donor-Recipient Matching: Automated reminders and AI-based scheduling improved donor participation and enabled faster, more efficient matching of blood units to patients during emergencies [29].
4. Safe and Monitored Storage Conditions: IoT sensors ensured real-time monitoring of temperature and humidity, safeguarding the quality of stored blood and minimizing risks of recipients [2,10].
5. Transparency and trust through Blockchain: Blockchain technology provided tamper-proof records of blood collection, storage and transfusion, thereby enhancing transparency, security and accountability in the system [2,19].
6. Stronger Donor Participation and Retention: AI-driven communication tools and predictive donor profiling increased engagement, helping to maintain an active and reliable donor base [35].

Disadvantages

1. Data privacy concerns: The integration of AI and blockchain requires the handling of sensitive donor and recipient information. Ensuring confidentially and preventing unauthorized access to these digital health records remain a major challenge [35,29].
2. System interoperability: Real-world implementation is hindered by differences in hospital and blood bank management systems. Lack of standardized protocols makes it difficult to achieve smooth data exchange across institutions [17].
3. High cost of implementation: Establishing AI and IoT based infrastructures, such as real-time monitoring sensors and blockchain platforms, demands significant financial investment, which may not be feasible in resource-constrained settings [24].
4. Real accessibility issues: While urban hospitals may adopt such technologies, rural and smaller blood banks often lack the required digital infrastructure. This creates an imbalance in access to safe and efficient blood services [35].
5. Ethical considerations: The use of blockchain and AI raises ethical questions regarding ownership and control of medical data. Concerns include informed consent from donors, possible misuse of predictive analytics and over-dependence on automated systems in life critical decisions [29].

Future Scope of AI in blood bank management

The integration of artificial intelligence, blockchain and IoT into blood bank management is still at a conceptual and pilot level but it holds significant potential for future development. Expanding these systems on a national sand global scale can transfusion medicine into a safer, more transparent and efficient service.

1. Nationwide and global interconnectivity: AI driven e-blood banks can be scaled into a nationwide, ensuring that every hospital and blood remains digitally linked. This wound makes it possible to locate rare blood groups instantly and reduce regional disparities in access [17,35].
2. Integration with hospital information systems: Linking e-blood banks with electronic health records (EHRs) and hospital databases can provide real-time updates on patient requirements, donor histories and inventory and accurate transfusion practices [24].
3. Enhanced donor engagement: AI-based communication tools can evolve into intelligent platforms that track donor health, send automated reminders and provide wellness feedback. This will help in improving long term donor retention and strengthening voluntary blood donation programs [17].
4. Expansion into rural areas: A crucial area for future research is addressing the digital divide. Affordable, low-resource AI and blockchain models can be developed for rural and semi-urban blood banks to ensure equitable access [35].

5. Research on ethical and ethical and legal frameworks: As a digital blood bank expand, future studies must focus on creating strong legal and ethical frameworks to protect data privacy, ensure informed consent and regulate the use of predictive AI models in clinical decision making [29].

V. CONCLUSION:

Ensuring a safe and sufficient blood supply continues to be a major challenge for healthcare systems worldwide [35]. Traditional blood bank practices often struggle with donor shortages, wastage, limited traceability and delayed emergency responses. These limitationshighlight the urgent need for smarter and more reliable approaches. The integration of AI, Bloackchain and IoT presents a promising pathway to overcome these barriers [24,29]. AI can forecast demand and optimize stock, IoT ensures safe atorage through real-time monitoring and blockchain secures transparent donor-recipient records. Together, these innovations create a system that is more efficient, trustworthy and responsive. While the potential benefits are significant, challenges such as data privacy, high implementation costs and interperability issues much be addressed before widespread adoption [17,35]. With careful research, ethical safeguards and gradual implementation. AI-based blood bank systems can evolve into a sustainable model that not only improves availability but also builds public confidence in blood transfusion services. Ultimately, the future of blood banking lies in combining that innovation severs its true purpose:saving lives when they are needed most.

VI. DECLARATIONS:

Ethics approval and consent to participate
Not applicable

Availability of data and materials
Not applicable

Competing Intrest
The authors declare that they have no competing Intrest

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VII. AUTHOR'S CONTRIBUTIONS:

SK initiated the idea of the manuscript, guided the overall structure and provided continuous supervision and critical revisions. IB carried out the literature search, drafted the manuscript and contributed to refining the final version. Both authors discussed the content, reviewed the manuscript in detail and approved the final submission.

VIII. ABBREVIATIONS

1)Artificial Intelligence-AI
2)Machine Learning-ML
3)Internet of Things-IoT
4)Radio Frequency Identification-RFID
5)Electronic Health Record-HER
6)Transfusion-Associated Graft Versus Hot Disease-TA-GVHD
7)Hepatitis B Immune Globulin-HBIG
8)Rhesus factor-Rh
9)Cytomegalovirus-CMV
10)Ultraviolet-UV
11)8-Methoxypsoralen-8-MOP
12)National Institute for Health and Care Excellence-NICE
13)World Health Organization-WHO
14)Red Blood Cells-RBC
15)Acquired Immune Deficiency Syndrome-AIDS

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