Design of A Blockchain-based Model for Provision of Incentives to Rare Group Blood Donors

Leah Chebet Bunei	Prof.Simon Maina Karume	Dr. Ruth Oginga
Student	Senior Lecturer	Lecturer
Kabarak University Nakuru, Kenya	Kabarak University Nakuru, Kenya	Kabarak University Nakuru, Kenya

Abstract: A critical requirement in achieving universal healthcare in Kenya is to maintain a consistent and adequate blood supply in the blood bank. Rare blood group donors, specifically those with AB-negative, B-negative, A-negative, and O-negative blood types, played a vital role in providing life-saving support to patients with special medical needs. However, the scarcity of these blood types posed a significant challenge, especially during emergencies or periods of high demand. Donor motivation remained low due to ineffective incentive systems, as traditional blood donation management platforms often lacked transparency, poor donor identification, and delayed or inadequate reward mechanisms. To address these challenges, the researcher developed a blockchain-based model prototype designed to provide secure, transparent, and trustworthy incentives for rare blood group donors. The model featured a token reward module that automatically generated and distributed digital tokens to verified donors, allocating 250 tokens for AB−, 230 for O−, 200 for B−, and 150 for A−, which could be redeemed for benefits such as subsidized medical care, free checkups, preferential services, and T-shirts. To ensure data protection and regulatory compliance, the model employed encryption, access controls, and adherence to data privacy laws. The research adopted agile methodology in prototype development. In conclusion, the blockchain-based model for provision of incentives to rare blood group donors demonstrated a viable and secure solution to the challenges in blood donation management, enhancing trust, transparency, and donor motivation, particularly among rare blood group donors.

Keywords: Blockchain, Model, Smart Contract, Confidentiality, Donors

1. INTRODUCTION

Blood donation is essential in healthcare worldwide, yet many blood donor units face persistent challenges in maintaining adequate supplies, especially for rare blood types. Blood transfusion supports surgeries, emergency care, and chronic illness treatment, and benefit patients facing life-threatening conditions, such as leukemia and hemophilia, to live longer and with a higher quality of life. The World Health Organization emphasizes the need for safe blood and blood products, particularly for individuals with rare blood types that are critical yet often in short supply (World Health Organization, 2021).

Despite many awareness campaigns, it is still hard to keep enough blood reserves available at all times, which makes it even worse for rare blood groups. The rare blood types include AB negative (AB-) which is the rarest blood types found in less than 1% of the population, B negative (B-) is another relatively rare blood type which 2% of the population has, A negative (A-) present in about 6% of the population and O negative (O-) which is the universal donor type found in about 7% of the population (Debele et al., 2023). However, finding and encouraging donors with these rare blood types is difficult, especially when their blood is needed quickly. Therefore, it is important to have a reliable, motivated group of rare blood group donors to meet demand (American Red Cross, 2023).

Ensuring the availability of blood is very important for saving human lives; thus, every drop of blood counts. In a country like Kenya, seven people need a blood transfusion every ten minutes (World Bank, 2022). The COVID-19 (coronavirus) pandemic in 2020 worsened the situation, as only 16% of the 1 million blood units required were collected (World Bank, 2022).

Globally, the policies that govern blood donation are typically guided by a combination of international guidelines, national regulations, and local health standards. These include the World Health Organization, which provides global guidelines and standards for safe blood donation practices (WHO, 2010). We also have the American Association of Blood Donor Units (AABB),

which is responsible for setting standards for blood donor units and transfusion services in the United States (AABB, 2021). Furthermore, the United States Food and Drug Administration (FDA) regulates blood and blood products to establish quality standards and safety (FDA, 2020).

In addition, the European Blood Alliance is responsible for providing support and guidance to blood services across Europe (European Blood Alliance, 2020). Moreover, the National Blood Transfusion Service (NBTS) may have its own governing body responsible for setting specific policies regarding blood donation, safety protocols, and donor eligibility criteria (National Health Service Blood and Transplant, 2021).

One way to encourage blood donation is by offering incentives or rewards. In countries like the United States and Australia, monetary payments are used to motivate donors. While this method has been effective in attracting some donors, it has also raised ethical concerns about treating blood donation like a commercial transaction (Murray et al., 2019). In Canada, blood donor units often provide gift cards or vouchers for local businesses to encourage donations (Harrison et al., 2018). In the United Kingdom, non-monetary incentives such as awards and public recognition are commonly used to acknowledge donors (Gonzalez et al., 2020).

Although traditional incentive methods have benefits, they also have problems. These include a lack of clear processes, the risk of misuse, and difficulty accurately tracking donations. Managing donor information and rewards in a single central location can also lead to privacy issues and delays, reducing the program's effectiveness and trust.

Blockchain technology offers a promising solution to these problems. Blockchain is a secure, transparent, and decentralized system that can keep donation records safe and unchangeable. It protects donor privacy while allowing quick verification and tracking of blood donations (Li et al., 2021).

Therefore, the design of a blockchain-based model prototype for the provision of incentives to rare blood group donors helps secure records, allows donors to track their blood donation history, and builds trust. Donors receive tokens for each blood donation, which must be redeemed for various incentives, including, but not limited to, subsidized medical care, preferential medical services, free medical check-ups, and T-shirts. This helps to increase donor participation and improve the supply of rare blood types in the blood banks.

To address regulatory challenges, the study implements data protection measures such as encryption and access controls to secure donor information and ensure privacy compliance, while also developing a non-monetary incentives model aligned with regulations (World Health Organization, 2023).

1.2 Statement of The Problem

Rare blood group donors play a critical role in the healthcare sector by providing life-saving support to patients with specific medical needs to live longer and with a higher quality of life. However, the scarcity of these rare blood types, namely AB-, B-, A- and O-, poses a significant challenge, especially in emergency or high-demand situations. Despite the crucial need for blood donations, donors may be less motivated to donate regularly due to a lack of incentives.

The traditional blood donation management systems are often not transparent, secure, trustworthy, or efficient. The existing system does not provide any motivation or incentives for blood donors. This discourages them from donating blood, particularly those individuals with rare blood types. However, due to these challenges, a transparent, secure, and decentralized solution was needed to improve donor engagement. Therefore, design of a blockchain-based model for the provision of incentives to rare blood group donors offered significant potential, providing immutable records, enhanced traceability, and ensuring that donors received incentives based on their donation history and blood type demand. This assisted in fostering a culture of appreciation and recognition for donors, thereby leading to better healthcare outcomes and saving lives.

1.3 Objectives of the Study

This research focuses on coming up with design of a blockchain-based model for provision of incentives to rare blood group donors that offers trust, transparency, and security, tailored to increase blood donation.

2. LITERATURE REVIEW

2.1 Overview of Rare Blood Donations Worldwide

Blood donation is a vital component of healthcare systems worldwide. Rare types are crucial for patients with specific medical conditions, such as those requiring frequent transfusions, and are also used during emergencies. The availability of these rare blood types can be a significant challenge in regions with diverse populations, where

certain blood groups may be underrepresented (D'Almeida, A., & Varela, P., 2020).

The individuals with rare blood include AB negative which is the rarest blood types found in less than 1% of the population, B negative is another relatively rare blood type which 2% of the population have, A negative present in about 6% of the population and O negative which is the universal donor type found in about 7% of the population (American Red Cross, 2023).

2.2 Existing Designs of Blockchain Models

Existing research highlights blockchain's growing application in healthcare, particularly in areas of data security, traceability, and donor management. Several studies have demonstrated the potential of blockchain in managing blood donation systems. For instance, Chakraborty et al. (2020) proposed a blockchain-enabled blood bank system that ensures transparency in donor-recipient matching and secure recordkeeping. Similarly, Shahnaz et al. (2019) designed a blockchain-based electronic health record system that improved trust and accountability, features equally critical to blood donation management.

Incentive-driven models have also been explored, although not specifically targeting rare blood groups. (Liu et. al., 2021). Discussed token-based rewards for healthcare data sharing, showing how blockchain can encourage participation through financial and non-financial incentives. In the context of blood donation, Bhatia & Sood (2021) suggested using smart contracts to automate donor recognition and reward distribution, thereby reducing administrative overhead and ensuring fairness. These designs demonstrate how blockchain can be adapted to motivate participation in sensitive and resource-critical areas.

However, literature specifically focused on rare blood group donors remains limited. Rare blood groups (such as AB−, B−, A−, and O−) face chronic shortages globally, making donor motivation critical (WHO, 2020). Existing blockchain models address general blood donation, but they rarely incorporate tailored incentive mechanisms for rare blood groups. This gap underscores the need for a blockchain-based prototype that integrates donor incentives such as token rewards, recognition badges, or priority access to healthcare services specifically for rare blood donors.

Thus, while blockchain has been successfully applied to donor management, healthcare data sharing, and incentive distribution, there is limited research on the unique challenges faced by rare blood group donors. Designing a prototype model for this niche area would bridge an important gap in both blockchain and healthcare innovation literature (World Health Organization, 2020).

2.3 The Blockchain Technology

Blockchain is a decentralized public ledger that supports creation of permanent and unchangeable records of data. This ensures transparency and trust among stakeholders by providing real-time access to donor information and donation histories. Smart contracts which are executable on blockchain platforms automate the verification and distribution of incentives as well as enhancing operational efficiency (Guo, et al., 2021).

2.4 Blockchain Smart Contracts

A smart contract is a self-executing program in which the terms of an agreement between two or more parties are directly written into code and executed on a blockchain network. This contract enables trusted transactions and agreements to be carried out without a central intermediary. Smart contracts offer transparency, security, and cost-effectiveness by eliminating intermediaries and enabling automatic execution when certain conditions are met, all without manual intervention (Taherdoost, 2023).

The blockchain smart contracts provide a health-centered system in which the rare blood donor owns the records, decides who can access the information, and cannot delete it, thereby solving trust issues. Interoperability can also be provided where blockchain acts as a catalogue listing all donors' records and histories.

2.5 Benefits of the Blockchain

According to Patel and Sharma (2023), blockchain technology offers several significant benefits, making it well-suited for applications that require transparency, security, and efficiency.

i) Enhanced Security

Blockchain transactions use cryptographic techniques such as hashing to secure data. Each transaction is verified by multiple nodes through consensus mechanisms (e.g., Proof of Work or Proof of Stake) before being added to the chain. Once recorded on the blockchain, data becomes immutable, making it extremely difficult to alter without the consensus of the network. Additionally, because information is stored across a distributed network rather than a single central server, it is more resistant to hacking and data breaches.

ii) Greater Transparency

Blockchain operates as a distributed ledger that ensures all transactions within a public network are visible to authorized participants. This transparency helps build trust among users, as every transaction, such as blood donations or incentive distributions, can be independently verified without intermediaries.

iii) Increased Efficiency and Incentive Tracking

Blockchain technology simplifies the tracking of donor incentives, particularly through smart contracts. These contracts automatically execute transactions such as distributing rewards once predefined conditions are met, ensuring timely and accurate delivery of incentives while minimizing administrative workload.

iv) Improved Traceability

Blockchain enables hospitals and blood donor units to create verifiable audit trails for all historical transactions. This capability improves traceability, prevents data manipulation, and reduces the risk of fraud in sensitive operations like blood management.

v) Decentralization

The decentralized nature of blockchain enables multiple stakeholders, such as hospitals, blood banks, and health authorities, to securely share information without relying on a central authority. This ensures collaboration while maintaining autonomy and data integrity.

vi) Cost Reduction

By eliminating the need for third-party intermediaries and establishing trust through data verification on the blockchain, organizations can significantly reduce operational costs for recordkeeping, auditing, and coordination.

2.6 Prototype Design Conceptual Framework
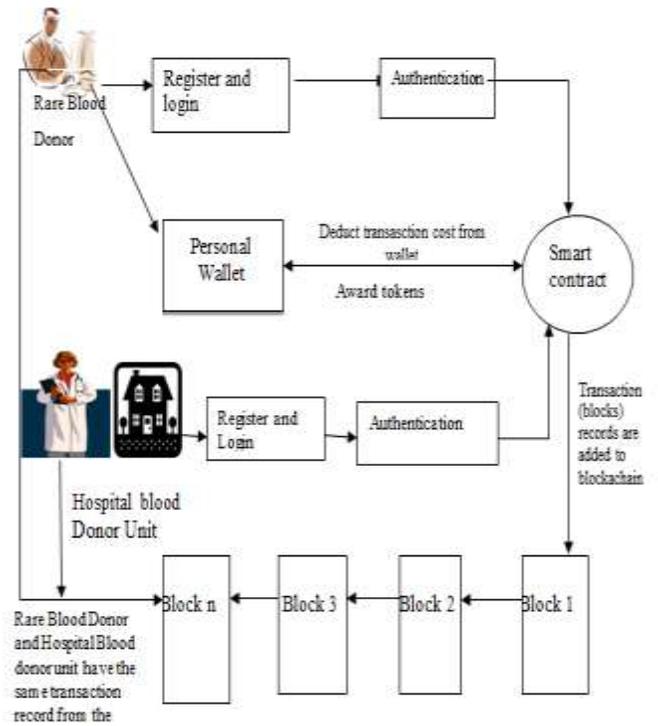
Source: Researcher, (2025)

The model has the following modules:

i) *User Registration module*: This was for the blood donor and the hospital staff,

ii) *User login and authentication module*: This was used in regulating access to authorized users only.

iii) *Personal Wallet*: This was used to securely stores reward tokens after successful rare blood donations.

iv) *Smart Contract*: This was responsible for generating tokens and creates immutable transaction blocks of records.

v) *Blockchain:* This was used to update all the information. The model was very robust, as it handled rare blood and did not reveal any authentication details, since the donor's records were a private matter.

2.7 Model Design and Operation

The figure below shows the model design and operation
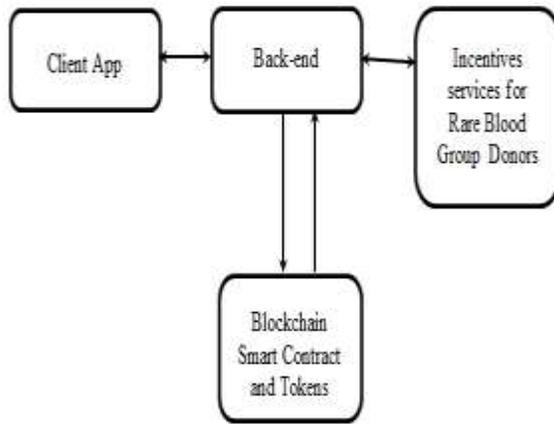
Source: Researcher, (2025)

i) *Client APP:* A client application makes a call to the back-end API that is responsible for authorization and authentication. The request is then passed to the blockchain smart contract, and a unique request ID is generated. After the donor's successful donation, the backend receives the donation notification and forwards it to the smart contract for execution. If the donation is successful, the user receives the tokens, and the hospital is responsible for updating the blood donation record, for example, by one unit of blood. The admin/ hospital then update the model.

ii*) Back-end:* This module manages the communication between the application and the blockchain, including interactions with smart contracts that track blood donations and incentives. It handles donor and hospital account creation, transfers tokens as rewards for donations, and facilitates exchanges or updates between participants. Essentially, it ensures that all donor information, donation history, and reward transactions are securely stored, verified, and processed in real time.

iii*) Incentive services for rare blood group donors*: This provided incentives for rare blood group donors by notifying the backend whenever a donation was made.

iv) *Blockchain smart contract* and tokens: upon receiving a verified blood donation update from a donor, a smart contract is executed to generate a token that facilitates the provision of incentives to rare blood group donors.

3. METHODOLOGY

This study adopted a mixed-methods research design, combining quantitative and qualitative approaches to provide a well-rounded evaluation of the blockchain-based model for the provision of incentives to rare blood group donors. On the quantitative side, the study relied on measurable indicators, such as donor participation rates and data integrity, captured through blockchain transaction logs. These numerical measures enabled accurate, transparent tracking of the system's performance.

At the same time, the qualitative dimension of the study focused on understanding the human side of the model. By examining patterns, behaviors, and contextual insights around donor engagement and trust, the research highlighted the motivations and perceptions that numbers alone could not capture. Integrating both approaches ensured that the findings not only demonstrated how effectively the model worked in practice but also explained why it worked and where improvements were needed. In this way, the mixed-methods design provided a balanced, holistic picture of the model's effectiveness and reliability.
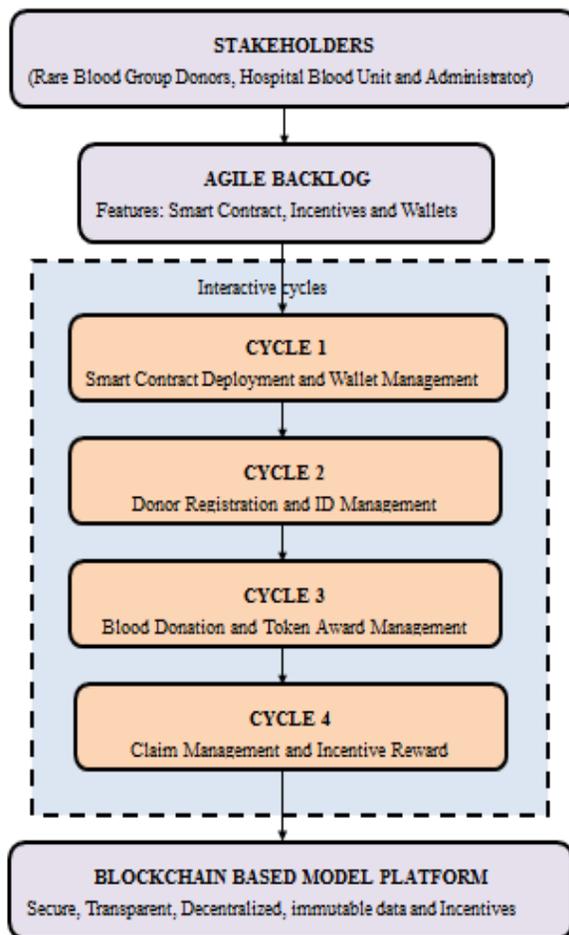
The design of a blockchain-based model for incentivizing rare blood group donors is best managed using the agile methodology, which promotes flexibility, collaboration, and iterative improvement. Agile allows developers, healthcare stakeholders, and donor representatives to co-create solutions in short, incremental cycles, ensuring that the evolving system remains transparent, secure, and responsive to user needs.

The Agile methodology is particularly suitable for this study because it offers the flexibility to adapt to the complex and evolving requirements of healthcare systems. This study must account for ethical concerns, regulatory compliance, donor privacy, and the secure management of transactions. Agile provides an iterative approach where features such as donor registration, identity verification, incentive distribution, and smart contract execution can be developed, tested, and refined in small increments. This reduces risks, ensures transparency, and allows for early identification of errors or vulnerabilities that could compromise the system.

Equally important, Agile emphasizes collaboration among developers, healthcare professionals, donors, and regulators, ensuring that the final product is user-centered and aligned with medical standards. Through continuous feedback and regular stakeholder involvement, the system evolves to meet donor expectations while maintaining trust and reliability. By delivering value early through incremental deployments, the blockchain model can begin

to provide transparency and accountability in the incentive process, even before full-scale implementation. Thus, Agile not only enhances system quality and security but also ensures sustainable value delivery in a sensitive healthcare environment.

The Figure below illustrates how agile methodology was applied in the design of a blockchain-based model to provide incentives to rare blood group donors. It demonstrates the interaction between stakeholders, iterative cycles, and the final platform.

Source: Researcher, (2025)

4.1 Security and Operational Requirements

Security and operational requirements during the design and implementation of a blockchain-based model for incentivizing rare blood group donors were essential to ensure the model remained transparent, trustworthy, secure, and operationally efficient.

Below was a detailed explanation of the security and operational requirements of the model:

i) *Blockchain Immutable Ledger*: The blockchain ensures that once blood donation records are written, they cannot be altered by anyone, and that each donor's contribution is recorded permanently.

ii) Digital signatures: Each blood donation transaction was cryptographically signed to ensure that only legitimate donors with rare blood groups could submit blood donation records and claim incentives.

iii) *Encryption:* Rare blood donor's personal information, such as identity, was protected using encryption methods to secure data where the same key is used for both encryption and decryption.

4. Users Overview and Interactions with the Blockchain

The blockchain-based model for incentivizing rare blood group donors involved several key participants who interacted within a secure, controlled digital environment. Each user played a specific role in ensuring that the system functioned effectively, maintained data integrity, and upheld ethical and privacy standards.

i) *Rare Blood Donor:* The rare blood donor registered through the application by providing verified personal information, including full name, email address, phone number, and blood type, which was confirmed by authorized hospital personnel. Once registration was complete, the donor could participate in blood donation drives. After each verified donation, the system automatically issued digital tokens through a smart contract. These tokens could later be redeemed for approved incentives. Donors interacted primarily with the blockchain through a digital wallet interface, ensuring transparency and traceability of rewards while keeping personal details secure.

ii) *Hospital Blood Donor Unit Officer:* This officer is an authorized member of the hospital's blood donor unit, played a critical role in validating and recording blood donations. They verified each donation, confirmed donor eligibility, and entered transaction details into the system. Their input triggered smart contract execution; ensuring rewards were distributed only upon legitimate confirmation. The officer's access was restricted to medical and operational data relevant to donation verification.

iii) *System Administrator*: The system administrator oversaw the operational and technical aspects of the blockchain system. Their responsibilities included monitoring donor incentive claims, approving or rejecting transactions flagged for review, and maintaining system

integrity. The administrator also ensured that system updates, data synchronization, and security protocols were effectively implemented. All administrative activities were logged to enhance accountability and minimize potential misuse.

The overview of different users and their interaction with the blockchain and the model as a system of smart contracts is shown in Figure below:
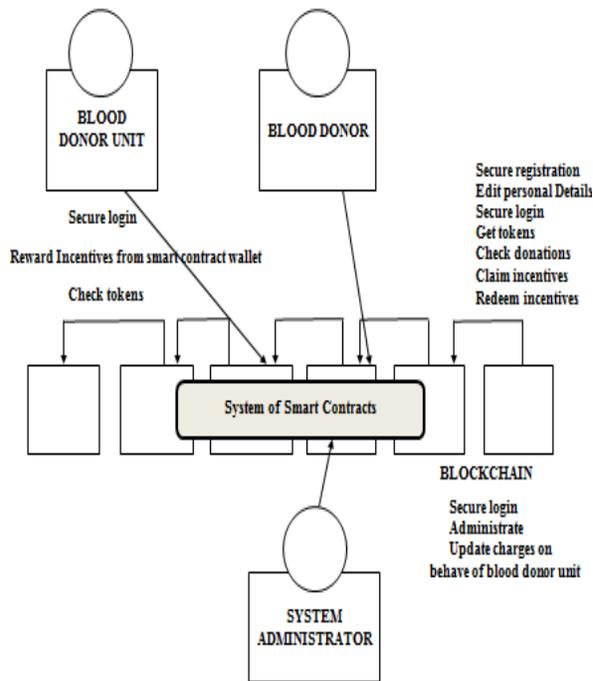
Source: Researcher, (2025)

5. RECOMMENDATIONS

Based on the findings of this study, several recommendations were made to strengthen the design of a blockchain-based model for the provision of incentives to rare blood group donors.

First, the model should incorporate strong security and privacy measures to safeguard donor information. Sensitive personal and medical data must be encrypted and stored securely off-chain, in compliance with global data protection standards such as the General Data Protection Regulation (GDPR) and the Health Insurance Portability and Accountability Act (HIPAA). Regular system audits and updates should be conducted to maintain security and ensure continued trust among users.

Second, it is essential to provide training and awareness programs for both hospital blood donor unit staff and donors. These initiatives will help users understand how the

blockchain model operates, how to interact with the system, and the benefits of participating in an incentive-based donation program. The model should be user-friendly, with an intuitive interface that simplifies donor registration, verification, and reward redemption.

Additionally, the system should be designed for scalability to accommodate an increasing number of users and transactions as adoption grows. Collaboration with hospitals, blood banks, and health authorities is also crucial to ensure the model integrates smoothly with existing healthcare infrastructure, complies with legal frameworks, and aligns with national blood donation policies.

6. CONCLUSION

Design of a blockchain-based model for provision of incentives to rare blood-group donors was found to be both feasible and beneficial, providing a secure, transparent, and trustworthy foundation for donor management and reward distribution. Through the use of smart contracts, the system automated incentives in a fair and tamper-proof manner, reducing administrative effort and increasing donor confidence. The iterative application of agile methodology further strengthened the model by allowing continuous refinement based on stakeholder feedback. Although challenges remained such as regulatory compliance, integration with existing systems, and the need for user-friendly interfaces the model overall demonstrated strong potential to enhance donor engagement, streamline operations, and improve the availability of rare blood types.

REFERENCES

[1] AABB (2021). Standards for Blood donor units and Transfusion Services. AABB Press.

[2] American Red Cross. (2023).The Role of Blood Donation in Healthcare. Retrieved from https://www.redcross.org/blood-donations

[3] D'Almeida, A., & Varela, P. (2020). Rare blood group donors: A Review of the Global Situation. Transfusion and Apheresis Science, 59(1), 102671. DOI: 10.1016/j.transci.2019.102671.

[4] Datta Suvro Sankha, Suhasini Sil & Saikat Mandal (2023), Rare blood group registry in India: current challenges and future perspectives. Front. Genet.14:1264853.

[5] European Blood Alliance. (2020). Position Paper on Blood Donation. Retrieved from the European Blood Alliance website.

[6] FDA. (2020). Guidance for Industry: Blood Donor Eligibility Regulations. Retrieved from FDA website.

[7] Goh, S. K., et al. (2021). "Health screening as an incentive for blood donation: A systematic review." BMC Health Services Research, 21, 354.

[8] Gollapelly, M., Reddy, V. S., & Sai Vamshi, K. (2023). Development and implementation of a web-based blood bank management system for efficient blood donation and distribution. Journal for Research in Applied Science and Engineering Technology (IJRASET). https://doi.org/10.22214/ijraset.2023.50493

[9] Gonzalez, J. M., et al. (2020). "Understanding the Motivations of Blood Donors: A Qualitative Study." Vox Sanguinis, 115(3), 229-237.

[10]Govender, L., Prakashchandra, R. D., Pillay, P., & Jentsch, U. (2021). Molecular red cell genotyping of rare blood donors in South Africa to enhance rare donor-patient blood matching. African Journal of Laboratory Medicine, 10(1), a1400.

[11] Guo, Y. M., Huang, Z. L., Guo, J., Guo, X. R., Li, H., Liu, M. Y., & Nkeli, M. J. (2021). A bibliometric analysis and visualization of blockchain. Future Generation Computer Systems, 116, 316-332.

[12] Kenya National Blood Transfusion Service (2021). COVID-19 Impact Report on Blood Collection in Kenya. Retrieved from https://www.knbts.or.ke/covid-19-report

[13] Kenya National Blood Transfusion Service. (2023). Annual Blood Collection Report. Retrieved from https://www.knbts.or.ke/annual-reports

[14] Kumar, A., & Singh, A. (2021). "Blockchain Technology in Blood Donation: A Review." International Journal of Medical Informatics, 148, 104396.

[15] Li, X., Wang, Z., Leung, V. C., Ji, H., Liu, Y., & Zhang, H. (2021). Blockchain-empowered Data-driven Networks: A Survey and Outlook. ACM Computing Surveys (CSUR), 54(3), 1-38.

[16] National Health Service Blood and Transplant (NHSBT). (2021). Guidance for Blood Donation. Retrieved from NHSBT website.

[17] Patel, R., & Sharma, K. (2023). Applications and Benefits of Blockchain Technology in Healthcare Systems. Journal of Emerging Technologies and Innovation, 10(2), 112–124. https://doi.org/10.1016/j.jeti.2023.02.004

[18] World Health Organization. (2021). Global Status Report on Blood Safety and Availability. Retrieved from WHO website

[19] World Health Organization (WHO). (2020). Global Status Report on Blood Safety and Availability. Retrieved from WHO.

[20] Zafar, M. H., Khan, I., Rehman, A. U., & Zafar, S. (2022, August 16). A novel blockchain-based model for blood donation system. EAI Endorsed Transactions on Context-Aware Systems and Applications, 8(1), e8. https://doi.org/10.4108/ eetcasa.v8i1.2546