BLOCKCHAIN-BASED BLOOD DONATION SYSTEM: ENHANCING TRACEABILITY IN BLOOD SUPPLY CHAIN MANAGEMENT

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ABSTRACT

With the ability to save three lives per donation, blood donation is an essential part of life preservation. This emphasizes the tremendous influence that blood donations can have on people's lives. This study explores the possibilities of a blockchain-based blood supply chain management system in Saudi Arabia. The goal of this study is to aid the blood management system with creative and practical solutions. By utilizing blockchain technology, the proposed system seeks to improve the blood supply chain's traceability, efficiency, and transparency, which should ultimately result in better patient care and fewer risks associated with blood management by carefully examining the shortcomings and difficulties.

KEYWORDS

Blockchain, Blood donation management, Blood bank, Ethereum & Blood Supply Chain Management.

1. INTRODUCTION

This system proposes the utilization of blockchain technology to address the challenges and limitations in blood supply chain management. The existing centralized systems in Saudi Arabia face issues such as a gap between blood donation and demand, single points of failure, limited tracking information, and concerns about the security of blood products. The proposed system focuses on the six stages of BSCM in Saudi Arabia, shown in Figure 1, excluding the medical stages. The proposed blockchain-based blood donation supply chain (BDSC) system seeks to track and deliver comprehensive information about blood and its constituent parts by utilizing the decentralized and immutable features of blockchain technology. The adoption of blockchain technology can facilitate real-time information sharing, secure tracking of blood products, and improve coordination between blood banks and healthcare institutions. This proposed system aids in the creation of creative solutions that enhance blood management procedures, guarantee blood resources are available, and enhance patient outcomes.

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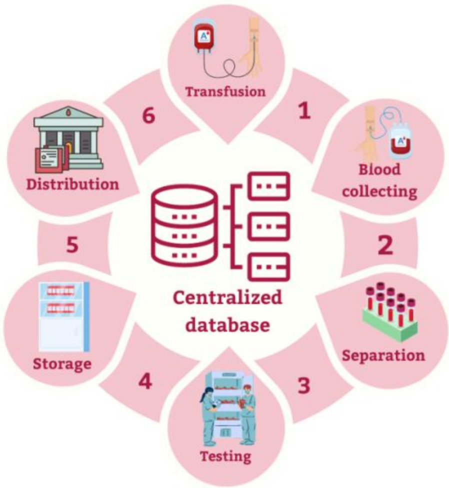

Figure 1. Stages of Blood Supply Chain Management [1]

Blood management is a complex system, there are a lot of factors that must be involved in the system. An interconnected series of blood management processes is called Blood Supply Chain Management (BSCM), which has six stages. There are six stages of BSCM in Saudi Arabia, which consist of blood collection, separation, testing, storage, distribution, and transfusion of blood [1, 2].

1. Blood collection: The donor arrives at the blood donation center and goes through a registration process. After being deemed eligible, approximately 450 ml of blood is drawn from the donor using a sterile needle. The blood is collected in sterile and sealed bags[1].
2. Separation: Red blood cells, plasma, and platelets are the three main components that make up whole blood. This procedure makes it possible to use every part [1].
3. Testing: For testing, the blood units are brought to the lab. The blood type of the donor is ascertained by a number of tests, which also check for infectious conditions like syphilis, hepatitis, and HIV. These examinations guarantee the blood donation's safety and suitability [1].
4. Storage: The blood components are stored under appropriate conditions. Platelets have a shelf life of five days; red blood cells can be stored for up to 42 days; and plasma can be stored for up to a year. During this time, the blood components are prepared for immediate transport when needed. All metadata, including all blood-related information, is stored in a central database [1].
5. Distribution: Blood is available at the Central Bank and delivered to hospitals. Hospitals have some units available in their clinics, but they may need more at any time or in emergency situations [1].
6. Transfusion: Finally, the blood components are transferred to patients in need [1].

A barcode is currently used in the blood donation system to store data about the blood bag. Each barcode that has been associated with a donation can be linked to all the information. Hospitals can access all of this data by scanning these barcodes [3].

1.1. Problem Statement & Significance

In the first stage, there is still a sizable discrepancy between the supply and demand of donated blood, even with the government's concerted efforts to raise blood donation rates. According to

Burnouf [4], there is a significant shortage in the global blood supply to meet the demand. In 2017, the world's need for blood was estimated at 304,711,244 units, while the available supply amounted to only 272,270,243 units. This shortage was particularly pronounced in 119 out of 195 countries, where insufficient blood supply hindered meeting their needs. The study emphasizes the critical need for strengthening blood distribution systems, boosting voluntary blood donations, and improving blood collection techniques in order to successfully address the world blood shortage. Blood donation is essential to saving lives because it can potentially save the lives of three people with just one donation [1].

According to a study in Saudi Arabia conducted by Jawaher Alsughayyir et al. [5], it has been projected that there will be a significant increase in the demand for blood in the future. This means that the need for blood transfusions and medical procedures requiring blood will rise. It is interesting to note that the study also discovered that the number of blood donors in a given year might not always exhibit a consistent pattern or trend over time. However, the demand for blood is expected to consistently increase over time. The increasing demand for blood underscores the need for individuals to regularly donate blood.

In the second and third stages, separation and testing are two stages that are not included in research because they are medical procedures. We will concentrate on these two stages from the perspective of tracking and providing details regarding the stage of the blood and its constituent parts.

In the fourth stage, centralized servers in the blood supply chain present a single point of failure and a high risk of data loss. This jeopardizes the availability of blood units and can have severe consequences. System downtime due to central server issues can be life-threatening [6].

In the fifth stage, this stage suffers from four problems, which are lack of detailed blood tracking information, lack of real-time information, lack of direct communication and transactions, and lack of blood conservation.

The shortcomings of the centralized blood management systems currently in place contribute to the first problem, which is the lack of thorough blood tracking data. Moreover, this problem causes the second problem, information is not reflected in real time. Since blood used for transfusions is eventually used in medical facilities and does not simply sit in blood banks, details regarding the quantity and rationale for disposal must be made explicit [6, 7]. The third issue is that medical facilities are unable to promptly obtain blood from the blood bank due to a lack of direct communication and transactions between them. The failure to effectively coordinate and connect medical institutions with excess blood stocks to those experiencing a complete shortage leads to the fourth problem, which is the wastage of blood [6, 8, 9].

It is interesting to note that more than 28 thousand units of blood and its components have been wasted in India, a country that claims to have a shortage of approximately 1.1 million (11 thousand) units of blood. Wastage of blood occurs when blood or any of its components are discarded rather than given to a patient. Lack of communication between areas with an oversupply of blood stock and others with a complete shortage is the primary cause of this imbalance [9]. Furthermore, in the United States, blood components waste rates typically fall within the range of 1% to 5% [10]. This poses a severe threat to the patient's life, as immediate transfusions are often crucial in emergency cases.

In the sixth stage, hospitals and patients often worry about the possibility of obtaining erroneous or infected blood in the supply chain. Disease transmission and the potential for blood products to be substituted or counterfeited are threats. An example of this problem happened in the last two decades. In the US, 600 patients contracted HIV, AIDS, and syphilis as a result of transmitting contaminated blood at blood donation facilities. This issue is pervasive in developing areas, e.g., in South Africa and India [11].

Between 2010 and 2017, there were reportedly over 14,474 cases of HIV infection in India as a result of transfusions of contaminated blood. Transparent blood inspection processes are crucial to establish trust, facilitate blood stock exchange, and prevent accidental transfusion of blood contaminated with diseases like HIV, hepatitis, and syphilis [9]. To ensure the secure delivery and distribution of blood units and to build confidence in their quality, it is crucial to maximize data visibility [8, 11, 12].

1.2. Proposed Solution

We could solve the challenges described above by establishing a BDSC public blockchain-based system. The system allows blood information to be tracked and validated at each stage of the supply chain until the final stage, avoiding exposure to any potential risks associated with a traditional supply chain. Additionally, direct contact between hospitals is made possible. Furthermore, the centralized database problem can be solved by using decentralized databases such as blockchain.

In the first stage, it is essential to actively encourage and promote blood donation in order to solve donor shortages and reduce the gap between blood supply and demand. Notifying blood donors whenever their blood is used is our suggested solution. This notification helps the blood bank keep them as regular donors by informing them of where it is and the usage of their blood, which may inspire them to donate once more. In addition, points are calculated as medical discounts for the donor as a reward for his donation.

A rewarding system is integrated with the proposed solution to encourage the donors to keep donating. According to Iajya et al. [13] and Kathleen et al. [14], these studies suggest that implementing a rewards system can be an effective strategy to encourage blood donation. By providing tangible rewards or benefits, such as gift cards, merchandise, or priority access to healthcare services, individuals are more likely to be motivated to participate in blood donation programs. The results of this study carry significant ramifications for blood banks and healthcare institutions that aim to enhance the availability of blood and satisfy the increasing need for suitable and safe blood products.

In the second and third stages, during blood separation and testing, additional details about the status of blood are inserted and marked with the appropriate expiration dates in the Quick Response(QR) tag, if tests for infectious diseases are negative. Efficient tracking systems guarantee that all parties involved, such as laboratory technicians and donors, are apprised of pertinent details regarding the state of the blood and its constituent parts.

In the fourth stage, to solve the problem of centralized databases, we propose a solution that represents decentralization of the blood supply chain to ensure that there is no single point of failure and avoid the risk of data loss.

In the fifth stage, we intend to solve the four problems associated with the fifth stage, which were mentioned previously. To solve the problem of the lack of detailed blood tracking information and the lack of real-time information, we propose a blockchain-based system that enables the tracking of blood components from collection to consumption, ensuring traceability and accountability. The use of blockchain ensures secure information visibility with encrypted and immutable records. This transparency enhances the inspection process, as detailed blood information is reflected in real-time, enabling efficient monitoring of the flow of blood and its associated information.

In order to overcome the lack of direct communication and transactions, a blockchain-based system can be used to transmit blood directly between hospitals in an emergency, doing away with the need for middlemen like central blood banks. By offering a unified platform for exchanging blood and its derivatives, blockchain empowers medical institutions to directly transact blood in urgent situations where obtaining it from a blood bank is not feasible. When the hospital does not cover the daily need for blood donations, an alert is sent to previous registered donors based on how close they are to the hospital to donate and fill the need. In addition to the lack of blood conservation, we propose a solution for direct blood exchange that helps reduce undue blood wastage by facilitating communication between regions with surplus bloodstock and those with absolute scarcity. Blood is matched based on the closest stock expiry date, which helps to avoid wastage due to expiry.

In the sixth stage, to limit the concern of hospitals and patients regarding the potential risks associated with erroneous or infected blood in the supply chain, we proposed a solution that utilizes blockchain technology with traceability to mitigate contamination risks in blood donation supply chains, ensuring reliable information at every stage and verifying blood source verification. Hospitals and patients can easily verify and track the complete chain of history associated with the donated blood, empowering them with in depth information and transparency.

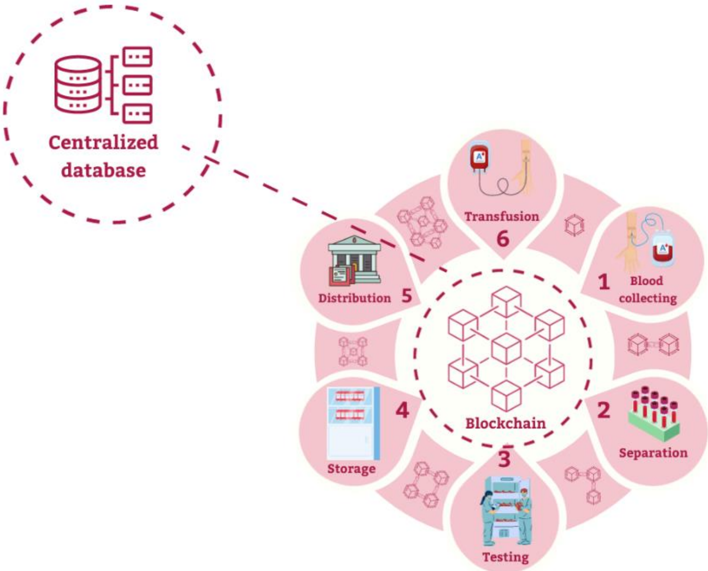

Figure 2. Stage of Blood Supply Chain Management Based on Blockchain

2. RELATED WORK

In [9], the paper proposes a blockchain-based system to enhance India's blood donation system, utilizing Hyperledger Fabric for secure access controls. The system monitors the entire process, from eligibility verification to transfusion, reducing waste and ensuring timely medical care. Testing was conducted in simulated real-world environments, but the study's evaluation is limited. Future work should focus on improving blood allocation, tracking blood derivatives, data security, and privacy, aiming to transform blockchain into a comprehensive blood supply chain management system.

In [6], the paper introduces a blockchain-powered system for improving blood cold chain management, utilizing a distributed ledger and Hyperledger Fabric for direct blood transactions between medical institutions. The system aims to enhance real-time data sharing and rapid response operations, targeting blood banks, blood test centres, and transportation vehicles. However, flaws include insufficient verification and evaluation in real-world settings.

In [8],the paper proposes a blockchain-based system for India's blood donation and transfusion, utilizing a decentralized ledger and smart contracts. The system aims to improve safety, transparency, and quality control, but faces weaknesses like data encryption, limited transparency, integration issues, and potential exposure of sensitive medical information.

The purpose of this paper [15], is to introduce a blockchain-based Blood and Product-Chain for blood supply chain management, utilizing a decentralized distributed ledger on the Hyperledger Fabric platform. However, it faces limitations such as prioritizing performance testing over real-world deployment and lacks an authorization mechanism for personal data privacy. The system also requires integration with broader healthcare roles and processes.

In [11], the paper proposes a blockchain-based blood donation supply chain solution using Ethereum blockchain and smart contracts to enhance trust and integrity. The system targets donors, blood centres, distributors, and hospitals as end-users. The system uses a private Ethereum network with smart contracts for transparency and traceability. However, the system faces weaknesses like limited deployment, lack of thorough testing, and insufficient focus on data privacy. Improvements include expanding blood delivery networks, ensuring patient data privacy, and conducting real-world pilots.

Our proposed solution will improve donor retention and rates through donor rewards programs and by informing donors where and how their blood was used. Many of these issues can be solved by integrating blockchain technology into our proposed system. We can eliminate the risk of single point of failure and data loss by shifting from centralized databases to blockchain-based decentralized data storage. Blockchain tracking of blood components can provide real-time visibility into the entire lifecycle, from collection to transfusion. Direct hospital-to-hospital blood transactions can be facilitated via blockchain during emergencies, bypassing blood bank delays. Smart contracts can match hospitals with expiring stock to hospitals with shortages, minimizing waste. Finally, blockchain can mitigate contamination risks and improve trust through supply chain transparency. Hospitals and patients can cryptographically verify the full history of a blood unit on the tamper-proof ledger. Similar systems are displayed in the following table 1 along with a comparison to our proposed solution.

Table 1 Proposed & Similar Systems Comparison

Features	Our proposed solution	Sivakamy Lakshminarayanan, et al (2020) [9]	Kim, Seungeun, et al. (2020) [6]	E.Sweetline Priya.(2022) [8]	Phuc Nguyen Trong et al. (2022) [15]	S. Sadri, A. Shahzad, and K. Zhang. (2021) [11]
Informed (notification) donor when used blood	Yes	Yes	No	Yes	No	No

Can patient Trace the blood	Yes	No	No	Yes	No	No
Tracking whole blood component	Yes	No	Yes	Yes	Yes	No
Can the hospital contact with donor when hospital need donation	Yes	No	No	No	No	No
Use Barcode / QR code	Yes	No	No	No	No	Yes
Donation points are calculated as a reward.	Yes	No	No	No	No	No

3. IMPLEMENTATION PLAN

The Sheryan System is an all-inclusive web application with a backend, user interface, and integrations that utilize an organized architecture. The system architecture of the Sheryan System illustrates the structure and interactions of its components, as shown in figure 3.It provides an overview of how the user interface, backend, and integrations are organized within the system. The user accesses the website through a browser. The user then logs in using MetaMask and performs MetaMask verification. Once validated, the user can access the application's front-end, which is implemented using HTML, CSS, and JavaScript frameworks like React. The user interface (UI) design is created using Figma. This user interface provides the graphical interface for users to interact with the web. On the backend, the system utilizes Solidity, a programming language for writing smart contracts on the Ethereum platform. The interaction between the front-end and the Ethereum blockchain is facilitated by the ethers.js library. The development environment for writing smart contracts includes Remix, an editor and simulator for Solidity, Ganache, a local blockchain network for testing and development, and Truffle, a popular development framework for Ethereum.

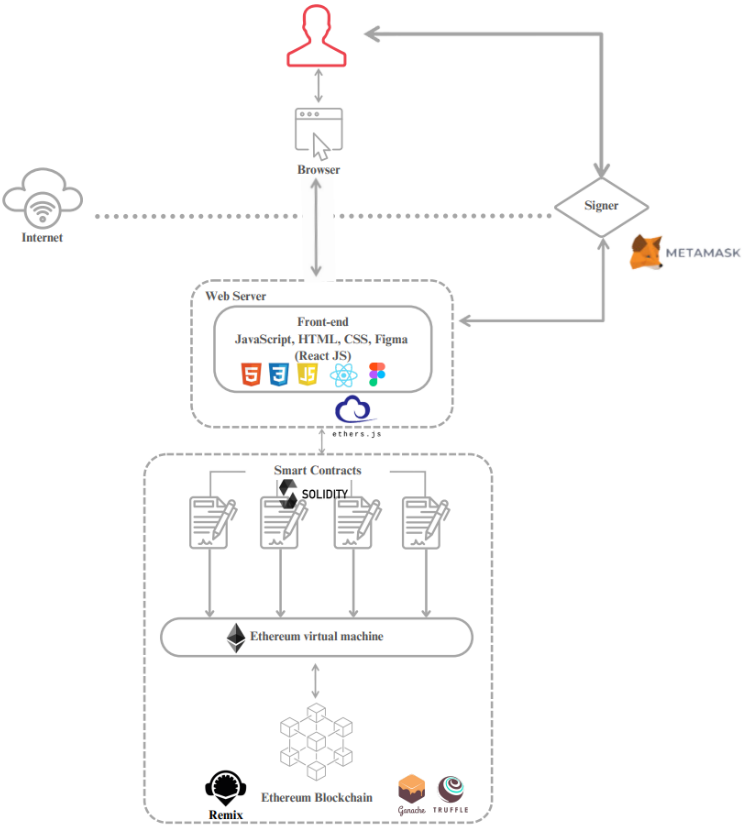

Figure 3. The System Architecture of Sheryan System

4. SYSTEM DESIGN

In this section we discuss the Sheryan System Data Flow, user registration process, admin functions and processes, hospital functions and processes of blood management, patient features and interactions and finally, donor functions and processes in sheryan system.

4.1. Users Registration in Sheryan System

By clicking on the button on the homepage, the donor will register. If the patients do not have any accounts, the admin will register them, and the hospitals will register them. They include entering the necessary information, such as their name, email address, phone number, address, and any other information specific to their position. To complete the registration process, the system needs the verification code to verify the user and extract the wallet address. The new registration was made by the system**.** Using their wallet address, users will log in to the system by connect wallet button in home page. Figure 4, represents the process flow for users' registration and login within the Sheryan System, illustrating the steps involved in these actions.

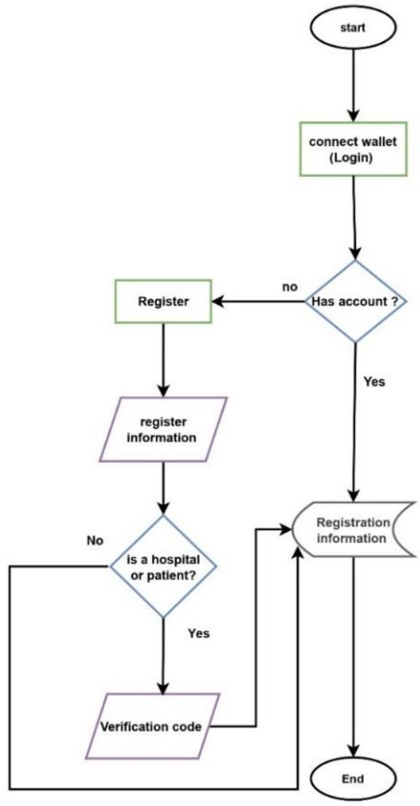

Figure 4. The Users Process of Registration and Login in the Sheryan System

4.2. Admin Functions and Processes in Sheryan System

The admin user will register automatically in code, admin just need to login by clicking the connect wallet button on the home page. The admin can add hospitals to make the system more authenticated. Also, can see all hospitals were added. The admin can logout of the system. Figure 5 shows the flowchart that illustrates the process of adding a hospital in the Sheryan System.

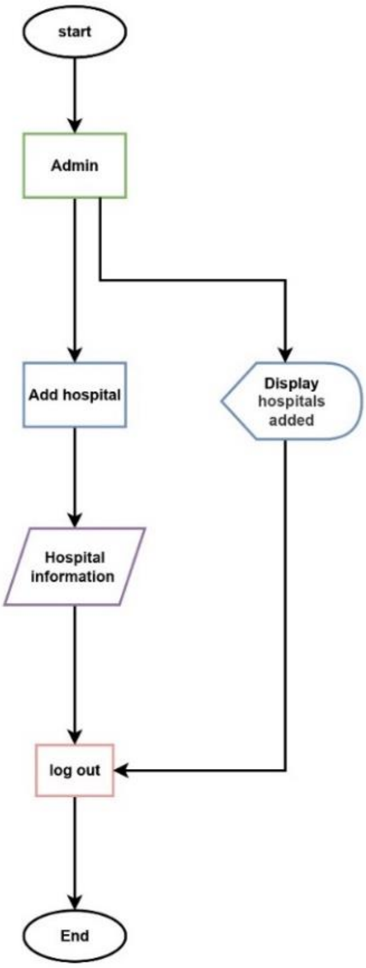

Figure 5. The Admin Process of Add Hospital in the Sheryan System

4.3. Hospital Functions and Processes of Blood Management in Sheryan

The hospital can add new donors to the system, track requests, and deliver unique QR codes for each donor. It also shows comprehensive donor information on the hospital page. The hospital sees requests on the request page, which they may accept or reject. If a hospital has a stack addition, clinicians can review the available extra donor blood on the extra blood notification page. Lab information records can be edited and shown on the lab page. The hospital may use the send notification page to notify donors when their blood is used or if there is an issue with the blood test results. Furthermore, in cases where the hospital cannot receive the daily volume of donations. In the add patient, the hospital can create an account for the patient to enable them access to the system. Lastthing, the hospital user can make changes to its information. The Hospital can logout of the system. Figure 6 shows the flowchart that depicts the process of blood management within the Sheryan System from the perspective of a hospital.

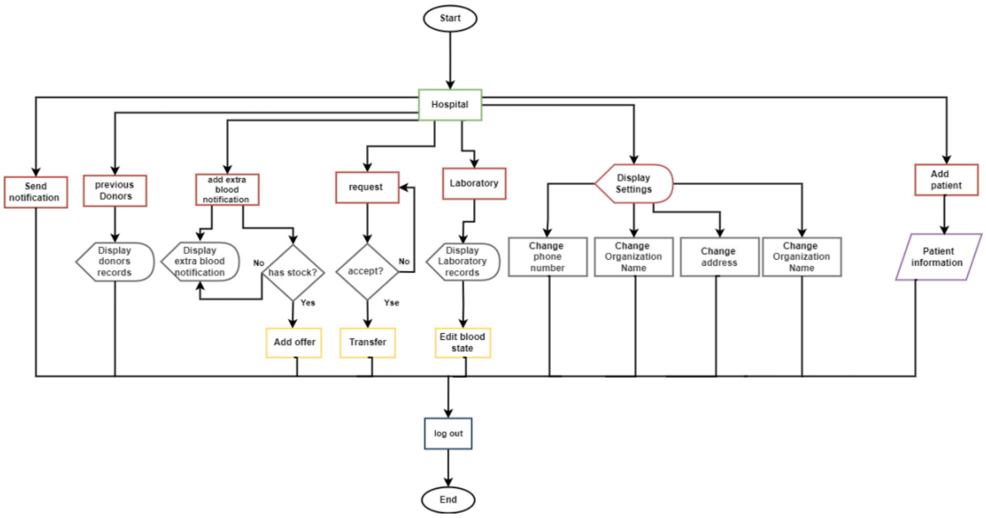

Figure 6. The Hospital Process of Blood Management in the Sheryan System

4.4. Patient Features and Interactions

The patient can view her or his information and change it. Also, track and view their blood-related information. Moreover, the patient can change personal information. The patient can logout of the system, as shown in Figure 7.

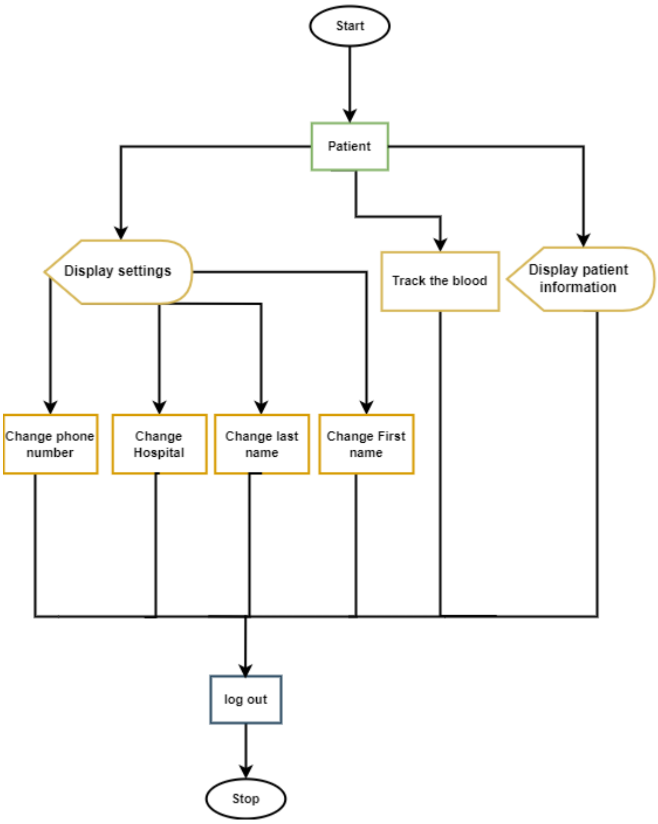

Figure 7. The Patient Process of Tracking Blood in the Sheryan System

4.5. DonorFunctions and Processes in Sheryan System

The "My Donation" page on the donor website allows the donor to check their donation history and associated details. Donors receive notice messages in one of three categories on the notification page. Donors can change their personal information by visiting the "Settings" tab on the setting page. The hospitals in need of donations are listed on the Donate Now website. The donor can logout of the system. Figure 8 illustrates the specific functions and processes available to donors in the Sheryan System.

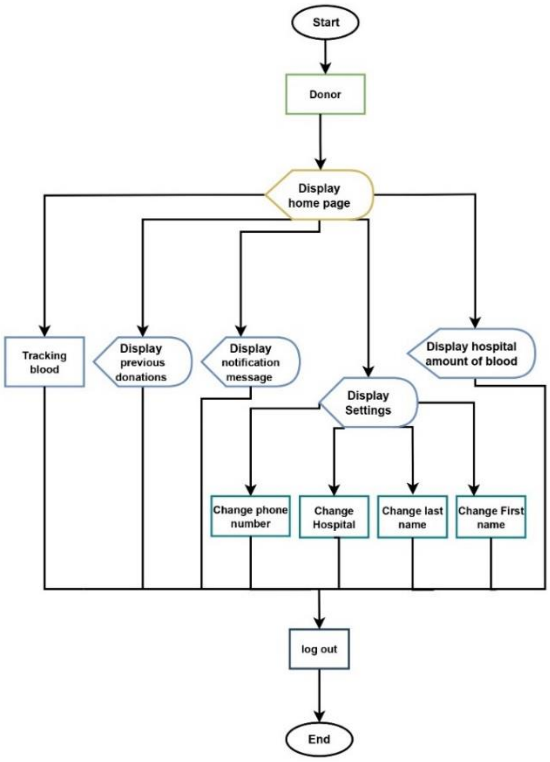

Figure 8. The Donor Specific Functions in the Sheryan System

4.6. Data Flow Diagram of Sheryan System

The data flow within the Sheryan System is shown in Figure 9, which also shows how information is processed and exchanged between the system's various components. A data flow diagram (DFD) can be utilized to represent process design. DFD is a structured analysis approach that indicates the flow of data, strings, integers, or arrays, passing through a software system, such as from one memory area or department to another. External data items are flowed from an internal data flow to a DFD via a processing function or process. The data flow diagram shows the specifics of flows and processing functions by decomposing the function at multiple levels. A data flow diagram must have the following elements: process, entity, data flow, and data storage. The process operates in a sequential or parallel manner, and information on the operation order is provided. [18].

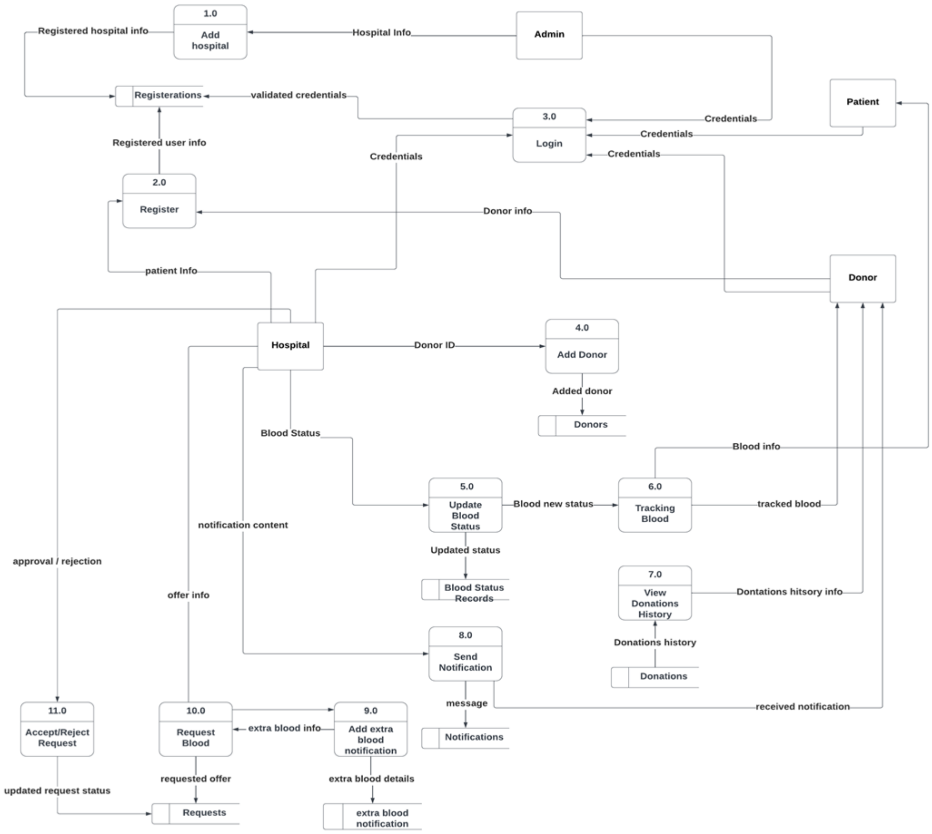

Figure 9. The Data Flow of Sheryan System

5. CONCLUSION

In conclusion, blood donation is critical in saving lives. Furthermore, blood donation shortages were particularly severe in over 100 countries. Many studies show that using blockchain would benefit the development of dynamic and effective blood management solutions in a variety of fields. In this paper, we have proposed a blockchain-based approach to improve blood supply chain management in Saudi Arabia. The Sheryan system seeks to address inefficiencies throughout the blood supply chain, from collection to transfusion. Moreover, Sheryan system includes rewards-based incentives, detailed data capture, direct hospital transactions, and historical traceability. Implementation could optimize blood management functions, improve coordination, and meet dynamic healthcare demands.

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