

AI-Enabled Support for Thalassemia Patients: A MERN Stack System for Donor Prediction, Alerts, and Assistance

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Abstract: *Thalassemia, a congenital blood disorder, requires lifelong management through blood transfusions to maintain stable hemoglobin levels. This creates ongoing challenges for affected individuals and their families. Timely access to compatible blood donors is critical for survival, particularly in severe cases that require frequent transfusions. Securing a suitable donor often becomes a major concern. In many cases, the process of arranging blood transfusions is stressful and slow, especially during emergencies. Conventional methods such as phone calls and social media appeals are unreliable and can result in harmful delays, negatively affecting patient health and increasing anxiety for both patients and caregivers. To address these issues, this paper presents a web-based support system designed to assist thalassemia patients by improving the coordination of blood donors. The system aims to reduce common problems in current transfusion practices, such as fragmented information, delayed responses, and lack of structured assistance. The proposed system provides donor management, blood request handling, and prediction of donor availability. It also integrates alert notifications and a chatbot to support patients and donors through a unified portal. Developed using the MERN stack (MongoDB, Express.js, React.js, and Node.js), the platform is designed for practical deployment and modular growth. Machine learning techniques are used to analyze donor history and behavioral patterns in order to estimate donor availability during urgent situations. This helps patients gain timely access to compatible blood. The system can send automated messages using services like Twilio and can integrate with healthcare platforms such as e-RaktKosh to discover additional donors and improve reliability. In addition, the platform includes an assistance component that offers information on transfusion schedules, donation guidelines, eligibility requirements, and navigation instructions. This is intended to make the system easier to use and to encourage user participation. Security is treated as a primary concern, with JWT-based authentication and role-based access control used to safeguard sensitive data and limit access based on user roles. Initial trials indicate that the system performs effectively in terms of task completion, coordination, and transparency. These findings suggest that the system can serve as a foundation for transfusion support, helping to improve access to care and quality of life for thalassemia patients.*

Keywords: Thalassemia, Predictive Donor Availability, MERN Stack, Artificial Intelligence, Smart Alerts, Healthcare Information Systems

I. INTRODUCTION

Thalassemia is characterized by reduced or abnormal hemoglobin production, which weakens oxygen transport and can lead to fatigue, weakness, growth problems, and organ damage. Regular blood transfusions are required for many patients to maintain safe hemoglobin levels and prevent serious complications. As a result, consistent access to



compatible blood donors is essential. Despite advances in medical treatment, locating suitable donors remains difficult, particularly in rural or underresourced regions. Traditional donor recruitment approaches are usually reactive and loosely organized. They often depend on informal contacts, phone networks, or social media and may not include proper screening or prioritization. This creates risks for patient safety and can lead to treatment delays, extended hospital stays, and reduced quality of life. Existing blood donation systems typically focus on donor registration and blood inventory management. However, they frequently lack real-time coordination between patients, donors, and healthcare providers. Many systems

do not incorporate predictive capabilities or patient-centric tools, which results in a gap between available data and timely patient care. Recent developments in web technologies and artificial intelligence provide an opportunity to address these limitations. Machine learning models can be used to predict donor availability or responsiveness based on historical patterns. At the same time, chatbots and conversational interfaces can offer round-the-clock assistance for patients and donors, providing guidance, answering common questions, and supporting routine tasks. This paper presents a healthcare support system designed to close these gaps for thalassemia patients. The system consists of modules for donor management, predictive availability analysis, smart alerting, and chatbot-based assistance, all integrated into a secure, scalable web platform built on the MERN stack. The overall goal is to streamline the transfusion workflow, shorten response times, improve transparency for all stakeholders, and use artificial intelligence to support better healthcare access and quality of life for transfusion-dependent patients.

II. LITERATURE REVIEW

Artificial intelligence has increasingly been applied in healthcare to improve clinical decision-making, predictive analytics, and resource management. Machine learning and deep learning methods can process large and complex datasets to support earlier diagnosis, individualized treatment planning, and outcome prediction. These techniques have also been studied in the context of donor-recipient matching, inventory control, and response optimization in critical care scenarios. Several works propose machine learning models to enhance donor-recipient matching in organ transplantation and blood transfusion. Such models commonly consider blood group compatibility, donor demographics, location, and donation history to refine matching accuracy. Deep learning approaches often outperform rule-based systems because they can capture non-linear relationships and subtle patterns. Previous studies also indicate that donor availability and participation are influenced by geographic accessibility, donation frequency, time since last donation, and historical responsiveness to requests. These factors can be used as features for predicting donor behavior and availability. Chatbots and conversational agents have been explored as virtual healthcare assistants. They are used for collecting medical history, scheduling appointments, performing symptom checks, reminding patients of medications, and providing educational content. Research suggests that chatbot interfaces can reduce routine workload for healthcare staff while improving accessibility for patients, especially those in remote locations. Natural language processing (NLP) allows chatbots to understand user queries and provide contextually relevant responses, which improves user engagement. However, many existing solutions are narrow in scope and address only specific aspects of the transfusion process. Blood donation platforms often emphasize registration and inventory tracking without predictive analytics or intelligent alerting. Healthcare chatbots, in turn, may operate separately from hospital information systems and are not tightly integrated with emergency coordination workflows. This lack of integration leads to fragmented data, partial automation, and reduced efficiency in time-sensitive scenarios. The literature therefore points to a clear gap in comprehensive, integrated transfusion support systems. While AI models and chatbot interfaces show promise, there is limited work that combines donor supervision, patient-facing chatbot support, predictive donor availability, and smart alerts within a unified, secure web platform. The system proposed in this paper aims to address this gap by combining AI techniques, web technologies, and healthcare services into a single coordinated framework for transfusion-dependent patients, particularly those with thalassemia.



III. PROBLEM STATEMENT

Thalassemia patients require frequent blood transfusions throughout their lives to maintain hemoglobin levels and overall health. Missing or delayed transfusions can cause serious health complications, increased hospitalization, and long-term damage to organs. Ensuring timely transfusion support is therefore critical. In practice, finding compatible blood donors, especially during emergencies, is a significant challenge for both patients and caregivers. This challenge arises from poorly organized donor databases, incomplete donor information, and weak communication among blood banks, hospitals, and patient communities. Donor-related information is often dispersed across multiple systems and informal channels, including hospital records, stand-alone blood bank databases, social media groups, and personal contact lists. This fragmentation slows down the process of locating suitable donors, verifying eligibility, and arranging logistics. The time lost during this process can be crucial in emergency situations. Existing systems for donor management are primarily designed for basic record-keeping and do not support predictive analysis.

They typically record donor details and transfusion events but do not actively use historical data, donor responsiveness, or geographic information to anticipate future donor availability. As a result, planning for transfusions tends to be reactive rather than proactive, and current systems do not offer intelligent decision support. Monitoring and coordination of the overall transfusion workflow are also limited. Stakeholders such as clinicians, blood bank staff, and caregivers often lack a unified view of ongoing requests, donor responses, and system bottlenecks. Without dashboards or real-time tracking tools, it becomes difficult to identify delays, measure performance, or optimize processes. Communication methods commonly used today—phone calls, messaging apps, and social media—are not reliable for time-critical coordination. There is no guarantee that potential donors will see alerts promptly, and there is usually no automated mechanism to confirm delivery or track responses. This leads to repeated follow-ups and manual effort, placing additional burden on patients, families, and healthcare staff. Patient education and support are another weak point. Many patients and caregivers have limited access to clear information about transfusion protocols, donor eligibility criteria, and what to expect before and after procedures. In the absence of integrated support tools, they must depend on busy healthcare workers or search for information on their own, which can cause confusion and stress. This research aims to address these problems by designing an integrated digital system that uses donor management, predictive modeling, automated alerts, and chatbot-based support within a single platform. The system is intended to reduce fragmentation of donor data, enable proactive planning, improve transparency and communication, and provide accessible support to thalassemia patients and their caregivers.

IV. PROPOSED SYSTEM OVERVIEW

The proposed system acts as an AI-assisted digital lifeline for patients who depend on transfusions. It is built using the MERN stack—MongoDB, Express.js, React.js, and Node.js—to provide a modular, scalable, and responsive solution suitable for healthcare applications. The system supports three primary user roles: patient, donor, and administrator. Each role is associated with specific permissions and features. Patients can manage their profiles, submit blood requests, monitor request status, and receive alerts. Donors can register, update their availability, and respond to donation requests. Administrators can validate donor information, manage user accounts, oversee requests, and analyze usage data. The overall design consists of several interconnected components, including user management, blood request handling, donor matching, AI-based prediction services, notification services, and chatbot interaction. When a blood request is created, the system validates the information and passes it to the processing logic. The AI module then considers blood group, location, donor history, and urgency to prioritize potential donors. External healthcare services, such as blood bank systems or government platforms like e-RaktKosh, can be queried to extend the pool of potential donors. A dedicated notification subsystem handles real-time alerts. It uses APIs and communication services such as Twilio to send SMS or email notifications to donors and patients. This helps reduce manual coordination in critical situations. In parallel, a chatbot module provides conversational support. It uses natural language processing to answer questions related to donation requirements, transfusion care, and how to use different features of the system. The chatbot is available at all times, which reduces the workload on healthcare staff for routine guidance. The system



architecture is modular by design, making it easier to update individual components or add new features without disrupting the entire platform. As AI models improve or healthcare integrations expand, they can be incorporated with minimal changes to existing modules. The combination of user-centered design, modern web technologies, and AI-based features aims to create a practical healthcare solution for patients with thalassemia who need ongoing transfusion support.

V. SYSTEM ARCHITECTURE

The system architecture is organized into multiple logical layers to ensure clarity of responsibilities, reliability, and ease of maintenance. The main layers are the Presentation Layer, Application Layer, AI Services Layer, and Data Layer. Each layer has a specific role and interacts with the others through well-defined interfaces.

The Presentation Layer is responsible for the user interface and user experience. It is implemented using React.js and provides separate views for patients, donors, and administrators. Patients can submit requests for blood, view the progress of their requests, and receive visual indicators or notifications when request status changes.

Donors can manage their profiles, indicate their availability, and view incoming donation requests. Administrators can monitor system activity, view donor and patient records, and oversee the overall workflow. The use of React.js helps create responsive, interactive pages that work well across devices. The Application Layer implements the core business logic of the system. It is built with Node.js and Express.js and exposes RESTful APIs for the frontend, chatbot, and AI modules. This layer handles user authentication and authorization, validates blood requests, performs donor search operations, and enforces role-based access control. JSON Web Tokens (JWTs) are used to secure communication between clients and the server, ensuring that only authenticated and authorized users can perform sensitive actions. This is especially important in a healthcare context involving personal and medical data.

The AI Services Layer enhances the intelligence of the system. It processes data such as blood groups, locations, donor histories, and response behaviors to support tasks like donor matching and availability prediction. Machine learning models are used to identify patterns in donor behavior, such as donation frequency, time since last donation, and typical response times. These insights help the system rank and recommend donors who are more likely to respond quickly and meet eligibility criteria, which is particularly useful during emergencies.

The Data Layer is built using MongoDB, a NoSQL database chosen for its flexibility and scalability. It stores various types of information, including user profiles, donor records, blood request logs, transfusion histories, and system analytics. Because MongoDB does not require a fixed schema, it can easily adapt to evolving data requirements in healthcare applications. Indexes on key fields such as blood group and geographic location enable efficient search operations, which is critical when identifying potential donors in time-sensitive situations. Access control mechanisms ensure that only authorized users and services can read or modify specific collections and fields. Figure 1 illustrates the layered architecture of the proposed system and the interactions between the components. By separating concerns across the presentation, application, AI, and data layers, the system achieves better fault isolation, maintainability, and extensibility. New AI models, real-time analytics, or external healthcare integrations can be added to the architecture without requiring major changes to the existing functionality.

VI. AI-BASED DONOR MATCHING AND PREDICTION

The AI-based donor matching and prediction module forms the core intelligence of the system. Rather than relying only on static donor lists, it analyzes historical and contextual data to support faster and more appropriate decisions.

The matching process begins by evaluating features such as blood group compatibility, donor age, geographic location, donation consistency, and previous response patterns. These attributes help filter and rank potential donors so that the system can focus on those who are both eligible and likely to respond. Geographic constraints are particularly important, as donors need to be within a reasonable distance of the medical facility or collection center to be useful during emergencies.



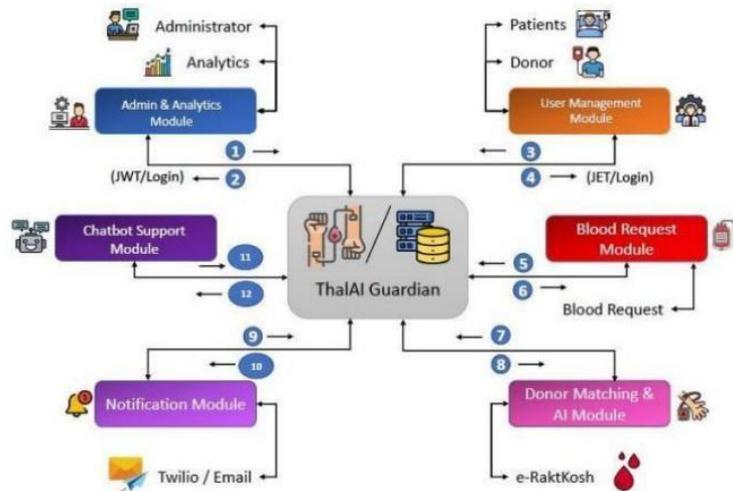


Fig. 1. Layered Architecture of the Proposed AI-Enabled Healthcare Support System

Behavioral analysis is also a key part of the module. By examining previous donation intervals, the time taken to respond to earlier requests, and adherence to eligibility guidelines, the system can identify donors who are more reliable and suitable for urgent needs. This reduces the effort required for repeated follow-ups and can improve the safety and timeliness of transfusions.

When the internal donor pool is not sufficient, the system can query external databases or services to identify additional donors. This hybrid approach, which combines internal records with external sources, helps maintain adequate donor availability, especially in high-demand periods.

VII. CHATBOT-BASED PATIENT ASSISTANCE

The system includes a chatbot module that acts as an interactive assistant for both patients and donors. Many users require clear and accessible information about blood donation, transfusion procedures, and system usage, and the chatbot is designed to address these needs.

The chatbot can answer frequently asked questions about eligibility criteria, preparation for donation, post-transfusion care, and how to register or submit requests on the platform. It can guide patients through the steps of creating a blood request or checking request status, and it can help donors understand how and when they may be contacted for donation. Because the chatbot operates automatically and is available at all times, it reduces the workload on healthcare staff for routine information requests. The chatbot is integrated with the system's database and services, which allows it to provide consistent and up-to-date answers based on current system data and rules. This integration helps build trust in the system's messages and improves user experience. By offering continuous support, the chatbot helps patients and donors feel more informed and confident when interacting with the platform. It also encourages regular engagement with the system, which can support better adherence to transfusion schedules and donor participation.

VIII. IMPLEMENTATION DETAILS

The implementation of the proposed system focuses on creating a clear, maintainable, and scalable structure while ensuring that the user interface is straightforward for all roles. The frontend is implemented using React.js along with HTML, CSS, and Bootstrap to build responsive pages for patients, donors, and administrators. Form validation and controlled inputs are used to improve data quality and reduce errors at the point of entry.

On the server side, Node.js and Express.js are used to build the backend API. The backend exposes RESTful endpoints for authentication, donor registration and management, blood request creation and tracking, notification scheduling, and



chatbot integration. JWT and bcrypt are used together to implement secure authentication and password hashing. MongoDB is used as the primary database. Collections are designed to represent users, donors, blood requests, transfusion histories, and log data. Appropriate indexes are created to optimize common queries, such as searching for donors by blood group and location or listing active requests.

For testing, tools such as Postman are used to verify API correctness, error handling, and security controls. MongoDB Compass assists in inspecting and validating the stored data. These tools help to ensure that the system behaves as intended and that data is stored and retrieved reliably.

Table I summarizes the main technologies used in the proposed system.

TABLE I: TECHNOLOGY STACK USED IN THE PROPOSED SYSTEM

Layer	Technology and Purpose
Frontend	React.js, HTML, CSS, Bootstrap for responsive user interfaces.
Backend	Node.js and Express.js for RESTful API services
Database	MongoDB for scalable and flexible data storage
AI/ML	Python, Flask, and machine learning libraries for prediction
Communication	Twilio API for automated SMS notifications
Security	JWT and bcr-ypt for authentication and data protection

IX. EXPERIMENTAL RESULTS AND ANALYSIS

The experimental evaluation of the system focused on assessing its functional correctness, responsiveness, and usefulness in realistic transfusion scenarios. The goal was to simulate typical workflows experienced by patients, donors, and administrators and observe how the system supported these activities.

Functional tests covered user registration and login, donor verification, creation and management of blood requests, donor search and selection, alert generation, and chatbot-based assistance. Each module was tested under both routine and emergency-like conditions to ensure that it behaved correctly and that the user interface remained clear and responsive. Test data included donor profiles with different blood groups, donation histories, and geographical locations. This allowed the donor matching and prediction logic to be exercised under varied conditions. The system successfully handled donor record creation and updates, triggered donor search based on incoming requests, and updated request status as donors responded or as administrators took action. Although the experimental setup was limited in scale, the results indicate that the system can coordinate key tasks in the transfusion workflow and provide timely support through alerts and chatbot guidance.

RESULTS AND ANALYSIS

Request Status

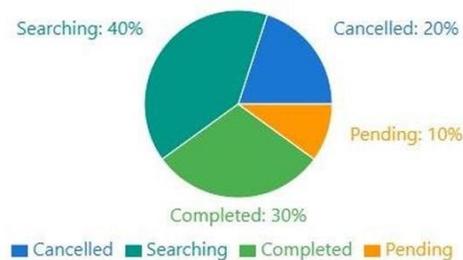


Fig. 2. Result Status



Urgency Distribution

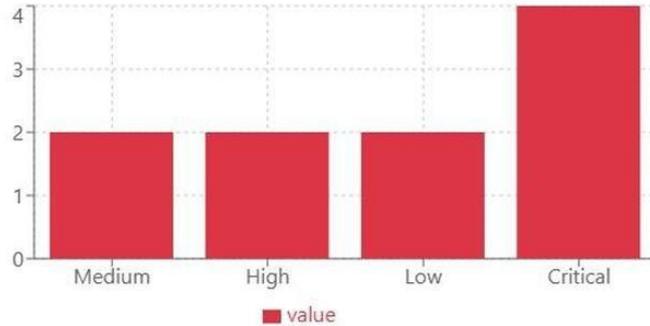


Fig. 3. Urgency Distribution

Blood Group Distribution

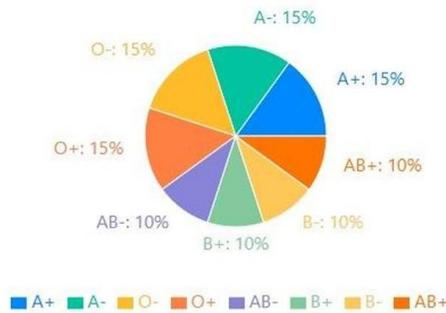


Fig. 4. Blood Group Distribution

Users Overview

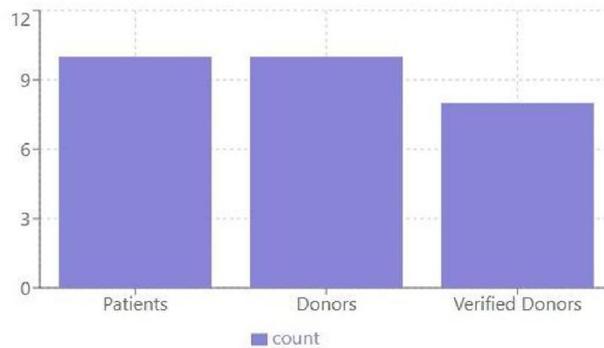


Fig. 5. Users Overview

X. DISCUSSION

The experimental results suggest that integrating artificial intelligence, automation, and real-time communication within a unified platform can significantly improve transfusion coordination for thalassemia patients. The proposed



system addresses several limitations of current practices, especially the dependence on fragmented communication channels and purely reactive donor searches. One notable improvement is the reduction in response time for urgent transfusion requests. By leveraging donor history and contextual features such as location and previous responsiveness, the system moves from a reactive approach to a more proactive form of coordination. This shift enhances preparedness, reduces uncertainty, and can contribute to better clinical outcomes. The centralized request tracking interface also improves transparency by allowing all stakeholders to observe the status of requests and identify potential delays.

The chatbot module enhances accessibility and usability by offering continuous, automated support. Patients and donors can obtain reliable information about procedures, schedules, and eligibility without requiring direct assistance from medical staff for every question. Because the chatbot is integrated with the platform's data and logic, its answers remain consistent with current rules and system behavior. Despite these advantages, some limitations must be considered. The effectiveness of donor prediction models depends heavily on the amount and quality of historical donor data. During the early stages of deployment, when the system has limited data, prediction accuracy may be lower. Successful real-world implementation also depends on sustained donor engagement, cooperation from healthcare institutions, and adherence to local regulations. Ethical and regulatory considerations are critical in health-care applications. Data privacy, protection of medical records, and compliance with relevant standards and policies must be ensured. This requires ongoing attention to security measures, access control, audit logging, and legal requirements as the system evolves and scales.

XI. CONCLUSION AND FUTURE WORK

This paper presented an AI-enabled healthcare support system designed to help thalassemia patients manage blood transfusion coordination more effectively. By combining predictive donor availability analysis, automated alert mechanisms, chatbot-based assistance, and centralized monitoring within a MERN-based web platform, the system addresses several key challenges of traditional, manual donor coordination. The system aims to improve efficiency, reliability, and transparency by reducing response times, limiting manual intervention, and enhancing user engagement. Experimental evaluation indicates that the platform is functionally stable and capable of supporting real-world transfusion workflows, particularly in conditions where patients require frequent and timely blood transfusions.

Future work will focus on expanding the intelligence and scale of the system. Possible directions include developing more advanced machine learning models for donor availability prediction, adding multilingual and emotionally aware chatbot capabilities, and pursuing deeper integration with national healthcare infrastructures and blood bank repositories. Large-scale pilot deployments and long-term studies will be needed to fully validate the system's effectiveness and impact. With continued refinement and collaboration with healthcare providers, the proposed platform has the potential to serve as a reliable digital lifeline for transfusion-dependent patients and to contribute to the broader development of intelligent healthcare support systems.

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