VOL. 10 NO. 9,
NOVEMBER, 2025
E-ISSN 3026-958X
P-ISSN 3027-1169

African Scholar Publications & Research International
www.africanscholarpub.com

Journal of Science Innovation & Technology Research (JSITR)

Bridging the Data Divide: A Framework for a Centralized Electronic Health Record System in Nigeria

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DOI: https://doi.org/10.70382/ajsitr.v10i9.051

Abstract

This study presents *MedSync*, an enhanced Electronic Health Records (EHR) system designed to address the fragmentation of patient data and the lack of interoperability among healthcare providers in Nigeria. Unlike traditional on-prem models, *MedSync* adopts a Software-as-a-Service framework that aims to enable hospitals invite patients and staff, and most importantly, allows each patient and their designated doctors to maintain and securely access centralized medical histories across multiple hospitals. The research began with a review of the country's healthcare landscape, analyzing prevailing EHR concepts, challenges, and organizational barriers to data exchange. Comparative case studies were conducted on existing local systems and international counterparts. Based on these findings, the system was implemented using the Django REST Framework, while the client-side was built with React and deployed on Amazon Web Services (AWS). The software incorporates an AI assistant that integrates the Gemini API, alongside multi-factor authentication with Google Authenticator. System testing and implementation documentation confirmed that the software met its core design objectives. The prototype performed reliably in simulated workflows and edge cases such as patient registration, clinician access control, and multi-hospital data sharing. The study highlights a practical foundation for future integration with live hospital environments and broader digital health adoption.

Keywords: Electronic health records, multi-factor authentication, cloud computing, mobile health, health information system, medical history.

Introduction

Nigeria, with a population exceeding 200 million, operates a multifaceted health system that encompasses public and private providers across primary, secondary, and tertiary medical levels (Adesola et al., 2024). The healthcare infrastructure is characterized by significant disparities between urban and rural areas. While urban centres have witnessed a great increase in the adoption of Electronic Medical Records (EMR) systems, particularly within private hospitals and federal medical centres, these systems often function as isolated databases. This lack of a centralized database and cross-integration between them hampers the ability to share critical patient information across different facilities, leading to fragmentation in care delivery (Momodu et al., 2024).

Hospitals across the country often operate isolated EMR systems, each functioning in silos without the capacity for intercommunication. This separation results in limited availability of patient records during emergencies, leading to delays, inefficiencies, and avoidable medical errors. Additionally, the inconsistency in how records are maintained from one facility to another contributes to a broader issue of data unreliability and loss.

The problem to be addressed by this study is the lack of a centralized, secure, and standardized electronic health record system that can bridge the gap stemming from disparate EMR platforms, enhance continuity of care, and improve healthcare delivery in Nigeria (Momodu et al., 202

The main aim of this study is to connect the fragmented nature in which patient data are currently managed by establishing a secure, cloud-enabled platform that will enable different healthcare providers across different facilities to securely access and share desired information about the patients.

The primary objectives of this research are to: Investigate the factors hindering EHR adoption and interoperability in Nigerian healthcare facilities, analyze the technical, organizational, and regulatory requirements for implementing a unified EHR system. Design and develop a cloud-based EHR solution that addresses the identified challenges, implement secure mechanisms for emergency access to patient records across different facilities, Evaluate the system's effectiveness in improving healthcare delivery and patient outcomes.

Case Study: National EHR Implementation in the United States of America

The United States was specifically chosen as a case study because of the vast differences in functional features between its EHRs and other systems in developed regions (European, Middle Eastern, and Oceania); hence, it was considered a suitable control reference to the desired Health Information System in Nigeria.

Since the early 2000s, EHR systems integrated into the North American health system have been primarily motivated by industry demands and government initiatives. Moreover, in a cross-sectional study conducted on a total of 371 health systems in both the US and non-US (A. Jay Holmgren et al. 2020), on average, US clinicians would spend more time per day using EHR services. They also receive more system-generated messages and use more functionalities than non-US-based clinicians, reasonably attributed to government policies regarding the “Meaningful Use Incentive Program,” which mandated secure messaging between

providers & patients and electronic prescribing. This resulted in nearly universal adoption of those capabilities by US health systems.

In 2016, the 21st Century Cures Act was enacted. This legislation made interoperability a legal requirement and prohibited data blocking by EHR vendors while mandating the use of standardized APIs to facilitate data access for patients and providers. This move arguably laid the groundwork for patient-centric systems and marked the shift towards empowering individuals with their health data.

In 2018, the Trump administration launched the *MyHealthEData* initiative, another significant step towards patient empowerment in the U.S. healthcare system. Spearheaded by the Centers for Medicare & Medicaid Services (CMS), it aimed to give patients greater access to and control over their personal health information by breaking down more data silos, making sure that medical records could follow patients across healthcare providers and settings.

Although the government has played a crucial role in driving the adoption and standardisation of these systems in their HIS, EHRs in the U.S. are not exclusively government-based; however, they are predominantly developed and maintained by private companies. The three dominant players in the U.S. EHR market are Epic Systems Corporation, Cerner Corporation (Oracle Health), and Meditech.

EHRs in the Nigerian Health Information System

The journey toward a comprehensive information system in the country has been complex and, at times, fraught with challenges unique to the nation's healthcare panorama. Nigeria's adoption has been hindered by a patchwork of issues resource limitations, infrastructure gaps, and inconsistencies in system compatibility across institutions (Agbo, S., 2024). Early attempts at EMR integration saw isolated pilot projects within urban hospitals, mostly in the private sector, where financial backing allowed for the requisite technology investments. However, in the public sector, progress lagged, affected by budget constraints, limited technical expertise, and frequent power disruptions (Oreoluwa O. et al., 2023).

The Health Information Systems Program in Nigeria (part of the broader *HISP* network) is a leading health informatics institution founded in 2006 to provide technical support for the Federal Ministry of Health and its partners. The National Health Information System is heavily reliant on the District Health Information Software 2 (DHIS2) provided and maintained by HISP Nigeria.

The *DHIS2* is the world's largest HMIS platform, utilised mostly in low- and middle-income countries. It is an open-source tool that simplifies health data collection and analysis. It aids in sharing information across different levels of healthcare systems and offers features such as dashboards, reports, and analytics when tracking health trends, monitoring outbreaks, and allocating resources effectively.

Each month, the ministry, in partnership with international organizations, dispenses a significant amount of resources to data collation, validation, and reporting processes, including manual uploads to the DHIS2 platform; still, despite these substantial investments, the state's data reporting rate remains disappointingly low, ranging between 45% and 60% (Alobo, G.,

et al., 2020). This highlights the urgent need for a robust electronic platform to improve data reporting efficiency.

RELATED WORKS

Taiwo Adedeji, Hamish Fraser, and Philip Scott (2022) developed a reusable Theory of Change (ToC) approach for the implementation and adoption of EHR systems, specifically using the Open Medical Records System (OpenMRS) and DHIS2 software facilitated by the NHIMS. However, a downside to the system is that it requires considerable systems administration and IT expertise to install, configure, and maintain servers for most healthcare practices. This barrier can be particularly challenging in resource-limited settings where budget constraints make it difficult to hire specialized staff for the implementation.

Inconsistencies in EHR data entry during patient encounters occurred because of several human, organisational, and systemic factors. The willingness of clinical staff to use the new system was lacking because of the perception that the system would add to their existing workload. This, of course, reflects a key institutional factor hindering EHR adoption, as stated in the objectives of this thesis.

The study highlighted that only a few healthcare professionals were keen on using the system. Lack of leadership motivation or incentive to use the system prevented health information officers, physicians, nurses, and midwives from understanding the need to work on data entry. Whenever there was a system downtime, there was usually no full-time health IT support technician on the premises to resolve the issue.

From the study, it is evident that, apart from having good software with familiar user interface components that are easy to understand with appropriate documentation and user guides; to ensure the sustainability of the system and that it achieves the goals the stakeholders and implementers have set out, there needs to be a multifaceted strategy in place that ensures healthcare practitioners see the value of EHRs; from policy enforcing leadership to easily accessible technical support.

Furthermore, drawing from my case study earlier on EHR implementation in the US, targeted funding, performance-based incentives, and legislation by the government will go a long way to support widespread adoption and, consequently, interoperability between these practices. A crucial limitation highlighted in the study itself was that the local healthcare professionals and stakeholders were not adequately involved in the analysis due to their unfamiliarity with the nuances of the Theory of Change (ToC) approach.

In another study by Momodu M. and Konyeha, S in 2024, it highlighted the need for a centralized patient records system. According to the Nigerian Health Facility Registry (NHFR), as of 2024, there are currently over 38,824 operational hospitals and clinics in Nigeria, across all levels of care. Professionals can enhance their awareness of a patient's health history and requirements by consolidating data from many sources into a centralized location. This can assist them in making well-informed decisions on treatment and care. In the study, several similar successful software applications that leveraged vast amounts of patient information in different countries were also mentioned, such as AccuHealth AI in Chile,

mHealth for Maternal and Newborn Health implemented in India, And Data warehouses used in France.

Manohara et al. (2021) offered a detailed exploration of a framework similar to this study, conducted within the Indian healthcare context. The study covers the use of EHRs for instant availability of health data to authorized personnel, and their efficient management on a national scale. Referencing India as a developing country, with vast amounts of hospitals and clinics and data problems as well, similar to Nigeria's predicament, it was also emphasized as a requirement that each department of every hospital should have a personalized application view in the proposed management system framework, with properly synced patient data such that there is no redundancy and duplication of records. After briefly explaining the history and evolution of health information systems, the authors then went on to document case studies of existing national EHR implementations in developed nations, overall. In Canada, England, and Germany at the time (2021), over 90% of their country's population made use of EHR systems implemented on a scale that spans their entire nation.

One of the most important takeaways from the underpinned research was the use of a cloud-based approach, which is essential to connect all practices/users of a nation's HIS into one single point to record and share patient data through the EHR.

In the study, security was also emphasised as a crucial aspect of the framework. Due to the sensitive nature of patient data, confidential information that is not expressly needed should be abstracted from patient data during transmission, even between departments of the same practice. To enable data sharing between different health practitioners securely, both Role-Based Access Control (RBAC) and encryption have to be employed. A major limitation of the study was that the proposed framework is a very high-level overview; it lacks specific details about the technical implementation.

Padam Sinha et. al. (2024) offer a detailed insight into the technical nuances of architecting and building an advanced solution to bridge the gap between patients and healthcare providers by leveraging six key technologies: MongoDB -A non-relational database, Express.js, React, Node, socket.io, and a third-party service for video conferencing called ZegoCloud.

The combination of the first four technologies, colloquially known as the MERN stack, enables full-stack development using a single language, JavaScript. This makes the development process cohesive and improves the readability, writability, and therefore maintainability of the codebase, allowing for rapid iterations. Their comprehensive guide also emphasises the impact of their selected stack on non-functional requirements of the software, such as scalability and flexibility, security, compliance, low latency, reliability, and enhanced real-time communication.

A deeper dive into their server-side Express.js code shows how every standalone conceptual component of their software with related functionalities was separated into modules, such as Appointment.js, Doctors.js, and Patient.js. Their programming conventions and technology stack will undoubtedly have a noticeable effect on my implementation in the following section. Nonetheless, the research and project implementation are limited only to scenarios where there is no more than one category of medical professionals or departments in a healthcare facility. In situations where there are pharmacists, lab technicians, and other respective specialists aside

from the primary doctor/consultant, who might need a controlled amount of sensitive patient information to proceed with their treatment, RBAC and other security measures are paramount.

On the topic of data security and access control, the research paper by Iishi Patel, Sambhav Jain, and others (2021) involved a relatively novel approach to data protection using Blockchain. The authors highlighted the issues with current medical record systems and accessibility in emergencies. Their proposition in the study was an EHR solution with an architecture that involved a two-module system (doctor portal and patient portal) that uses a database for which users can only perform CREATE and READ operations, a decentralised network for security, and Multi-Factor Authentication (MFA).

Candidly, their approach offers weighty security & data privacy advantages and a much-reduced risk of large-scale information theft or data augmentation, especially when MFA and patient data consent are factored in. On the other hand, critical drawbacks to using a decentralised platform are that, in real-world usage, it is much harder to maintain segregated systems than a unified one, and it will most likely incur higher infrastructure costs due to the use of multiple servers. If the system is not managed effectively, the chances of conflicting information would be much higher.

More importantly, local IT technicians at each server location will also be necessary for effective support, increasing maintenance costs even more. For the specific resource-constrained scenario examined in this study, a centralized system would be preferable; nonetheless, it should still incorporate strict medical personnel verification and MFA policies as they did.

In a systematic mapping study on privacy in EHR systems, Rodrigo Tertulino, Nuno Antunes & Higor Morais (2024), the trio affirmed that making these systems increasingly capable of guaranteeing privacy without compromising interoperability and performance was a major challenge. Moreover, the general lack of existing legislation that specifically defined a methodical approach towards data privacy in EHRs directly led to the creation of the policies we know today for certifying EHR systems, such as HIPAA, GDPR, ONC, and NIST.

Note that although privacy and security are closely connected, they are fundamentally distinct concepts and are usually misconstrued. According to Okegbile (2023), data security pertains to the measures that restrict access to personal information, ensuring it is available only to authorized individuals; however, privacy is the individual's right to control when, how, and to what extent their personal information is accessed, shared, or transferred to others.

In conclusion, the study examined an article on the development and presentation of a medical record system using the FHIR (Fast Healthcare Interoperability Resources) format for compatibility (Tz-Jie Liu, et. al., 2023). It accentuates the importance of standardizing schemas and protocols that enable different systems to communicate with each other. The researchers, based in Taiwan, put forward that the lack of a standardized framework for medical data exchange causes conflicting data interface methods between systems, requiring customization for each system by healthcare institutions. This has always been a major hindrance to effective data sharing between hospitals with established systems.

The inconsistencies in data formats require implementers to spend much more time on data parsing and mapping, resulting in slow integration of medical data, for instance, a medical practice or hospital may decide to use “Female” or “Male” to represent men and women in database fields, or M and F while others use “1” or “2” or even different field names like gender instead of sex, these discordant schemas add an extra layer of difficulty synthesizing medical data between health information systems.

The FHIR is an internationally recognised health information exchange protocol standardized by the HL7 organization in 2011. It provides a unified specification to solve the data exchange problem in the medical industry. FHIR provides schema definitions for XML (Extensible Markup Language), Turtle, and the more popular JSON (JavaScript Object Notation). In addition, it adopts Representational State Transfer (REST) APIs as a method for data transmission. In the article, a RESTful API is an architectural style for designing networked applications, based on the HTTP (Hypertext Transfer Protocol) and URI (Uniform Resource Identifier) Internet standards.

METHOD AND EXPERIMENTATION

Research Design

The methodological approach adopted to conceptualize and develop the system outlined in the previous sections involved an iterative, Agile-based development model combined with principles of the SDLC, visualized in Figure 2. This design ensured that critical components of the platform were developed incrementally, enabling continuous feedback, evaluation, and enhancement.

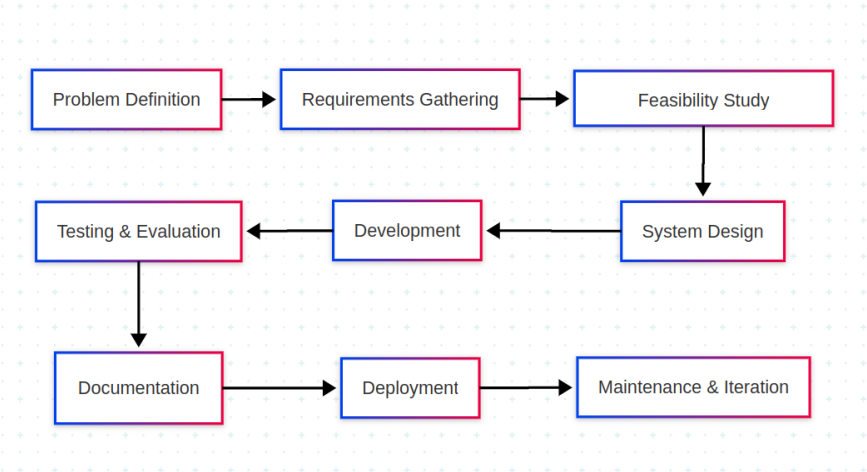


Figure 1: SDLC Narrative for the EHR System.

During and after requirement gathering, new objectives were incorporated into the development phase. From discussions with clinicians and students in healthcare fields and reviews of existing EHR architectures, the core requirements for a suitable prototype were distilled. These include the ability for doctors to create four structured types of medical records: test advisories, vitals, prescriptions, and medical notes, alongside functionality for

patients to view their records, book appointments, and engage in secure messaging with their assigned doctor.

Including a "lab technician" role for medics to update and process diagnostic test results was considered a priority for most. For simplicity, additional roles like Nurses and clerical staff were not included and may be implemented later on outside the scope of this research. The web application was set to be responsive for tablets, smartphones, and laptops, and to also be a PWA (Progressive Web Application) for better mobile support.

Given the scope and time constraint, a technical feasibility review was carried out to understand the features that were needed, the features that could be built within the time frame, and the overlap. Financial, technical, and time constraints were assessed, and compromises such as highly specialized roles and user types (aforementioned earlier, e.g, nurses, radiologists, and surgeons) and complete FHIR compatibility were temporarily deferred.

The architecture was drafted using modular design principles. Users are defined by distinct roles: admin, doctor, patient, and lab technician. Each medical record type was modeled with its own schema, enabling clear data categorization and scalability. On the frontend, reusable components built with ShadCN (React) were created to handle data presentation (e.g., vitals graphs) and form submission with dynamic validation.

As regards testing and evaluation, Chrome developer tools were used to verify the responsiveness of the web app on multiple viewports, and Postman was employed to test the response of each endpoint and assess other performance metrics. Clear internal documentation was written for the HTTPS endpoints and schemas using Swagger UI.

The complete application was containerized using Docker and deployed on a t2.micro AWS EC2 instance, running on Ubuntu 22.04 Operating System. The Django server runs behind an Nginx reverse proxy with Gunicorn as the WSGI server. The PostgreSQL database is hosted with AWS RDS, ensuring managed backups and high availability. Static files like profile images are uploaded to and served via Cloudinary, and the frontend is deployed separately with continuous build using Vercel. Post-deployment, the system is in a stabilization phase where bugs, edge cases, and usability issues are continuously addressed.

Tools and Technologies

As stated earlier, A Django-React technology stack is the foundational suite for the system, following insights gleaned from the literature review in the preceding section. Table 2 presents a quick summary of the major parts of the technology stack.

Table 1: ***Summary of tools and technologies used***

Typescript + React	**Built the responsive, interactive frontend.**
Python + Django	Powered the backend API and business logic.
PostgreSQL	Stored structured health records and user data.
Gemini AI	Enabled smart health insights and chatbot responses.
AWS	Hosted and managed cloud infrastructure.
Visual Studio Code	Cross-platform code editor with terminal support
Postman	Tested and validated backend API endpoints.

System Architecture

The design of the system follows a robust mult-tier architecture, carefully crafted to meet the scalability, performance, and security demands of modern healthcare environments. As shown in Figure 3, the architecture comprises three distinct layers on separate servers: the **Application Layer**, the **Database Layer**, and the **Presentation Layer**, as well as other cloud service integrations.

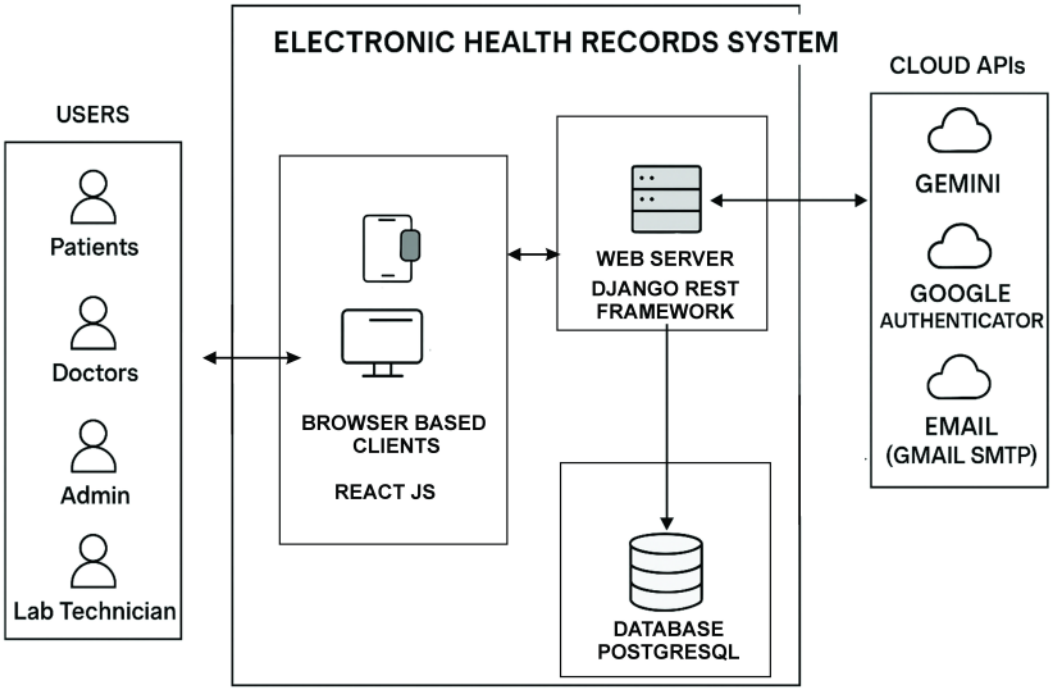


Figure 2: Architecture Diagram.

The modules above illustrate communication flow in the system. Users such as patients, doctors, admins, and lab technicians interact directly with the client, which then communicates securely with the web server. The server interfaces with cloud APIs like Gemini for AI, Google Authenticator for MFA, and Gmail SMTP for emails, while also querying the database to manage and retrieve records.

As explained in the second-level Data Flow Diagram (Figure 4), the flow of information in the system begins with the patient, who can book or view appointments through the Manage Appointments module, which connects to the Appointments Entity for scheduling and availability.

Patients can also view their health history via the Manage Medical Records module, which is linked to the Medical Records Entity and updated by doctors and lab technicians. Doctors access and update medical records, manage appointments, and communicate with patients through the Chats Entity. Lab technicians interact with the records entity to view assigned tests and submit results. Admins manage users via the Manage Users module connected to the Users

Entity, assign doctors to patients, and oversee appointments without having access to patient medical records.

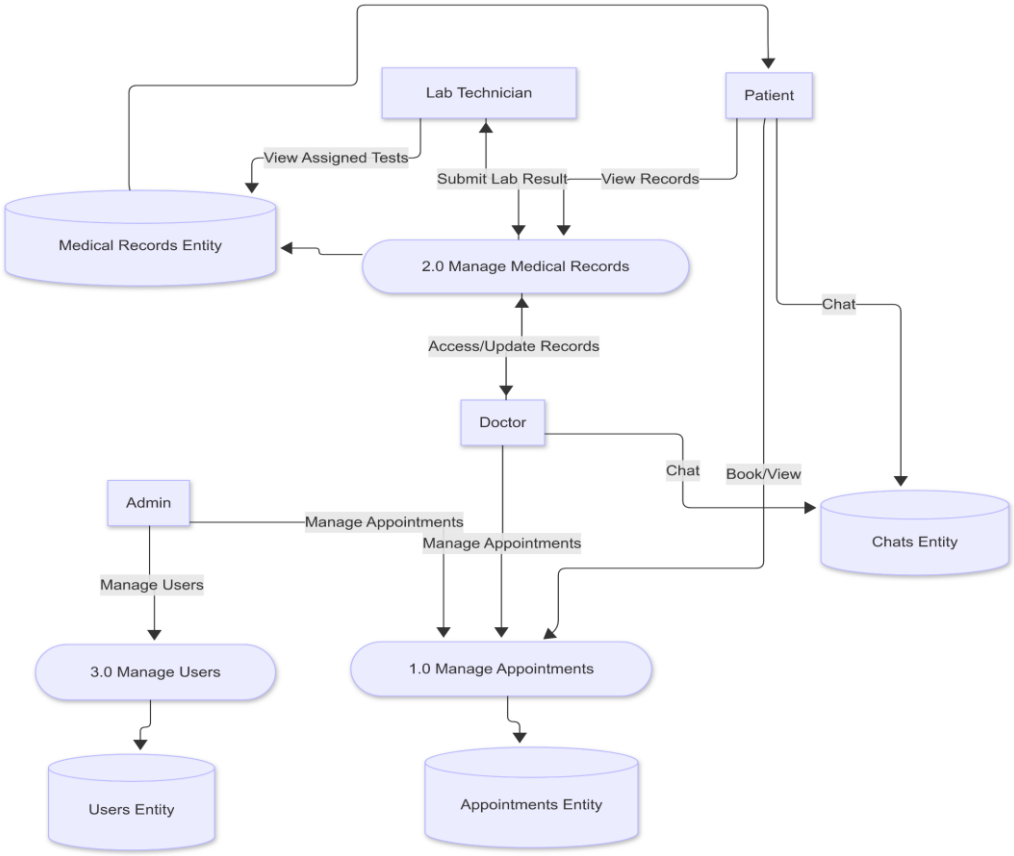


Figure 3: Second-Level Data Flow Diagram

Program Modules and Interfaces

User Management

User management is a foundational module where secure authentication and authorization through role-based access control are handled, ensuring appropriate information access across the app. The system recognizes distinct user types with specialized needs: administrators require privileged access for user management; patients need self-registration with identity verification; doctors require access to patient history; and lab technicians need specific permissions for viewing test/diagnostic orders and result submission. Figures 5 and 6 show two vital UI screens in the fully developed application.

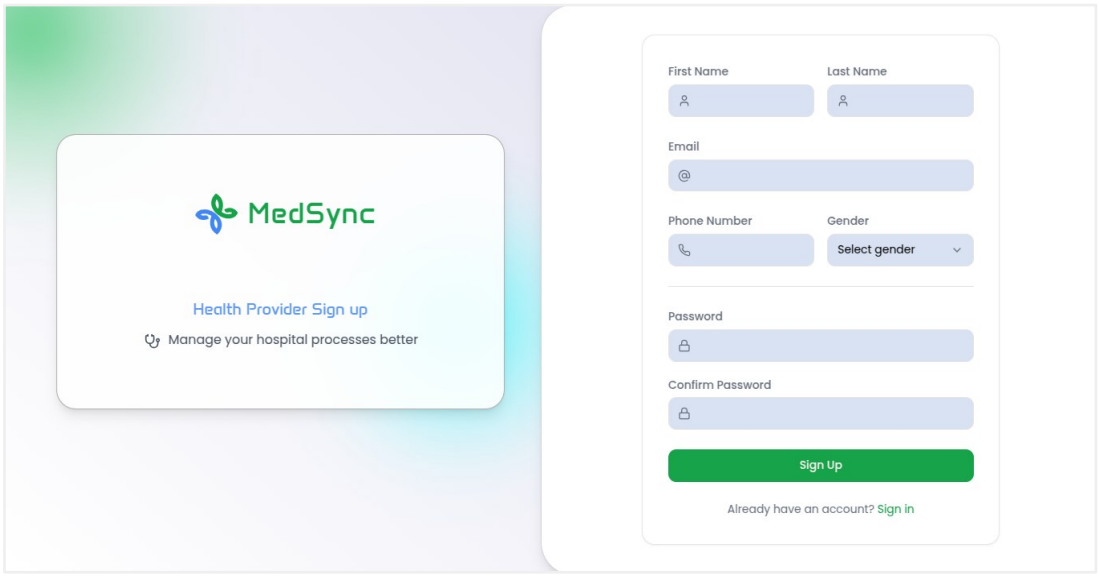


Figure 4: Health Institution Account Creation

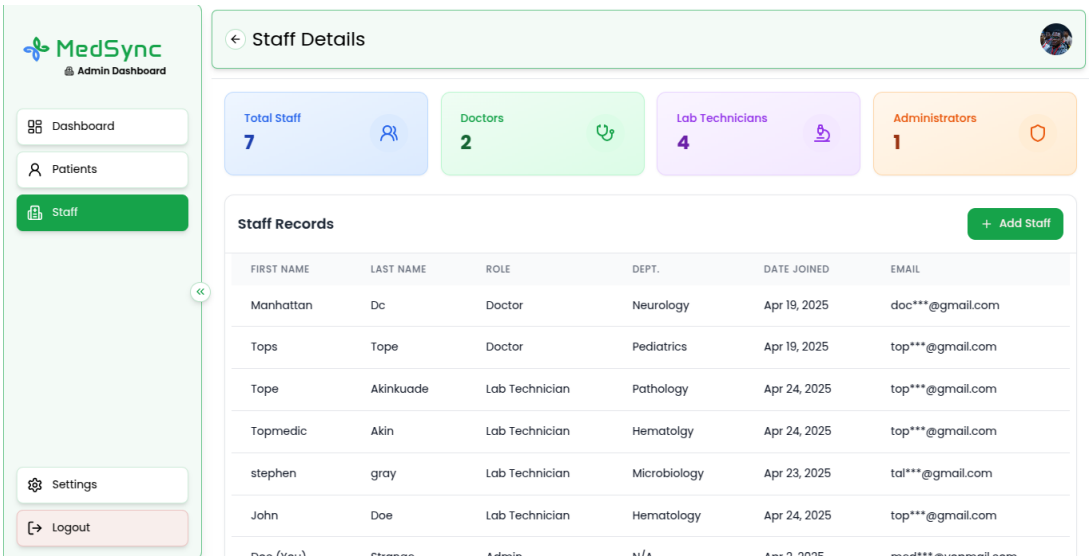


Figure 5: Admin View - All Staff

Appointments Module

The appointment system creates a streamlined scheduling interface where patients can view real-time provider availability, book appointments based on specialty needs, and receive automated reminders to reduce no-shows. Doctors gain visibility into their daily schedule with patient information context, allowing them to prepare for each encounter as illustrated in Figures 7 and 8, which depict the Appointment Scheduling Form and Appointment Details, respectively.

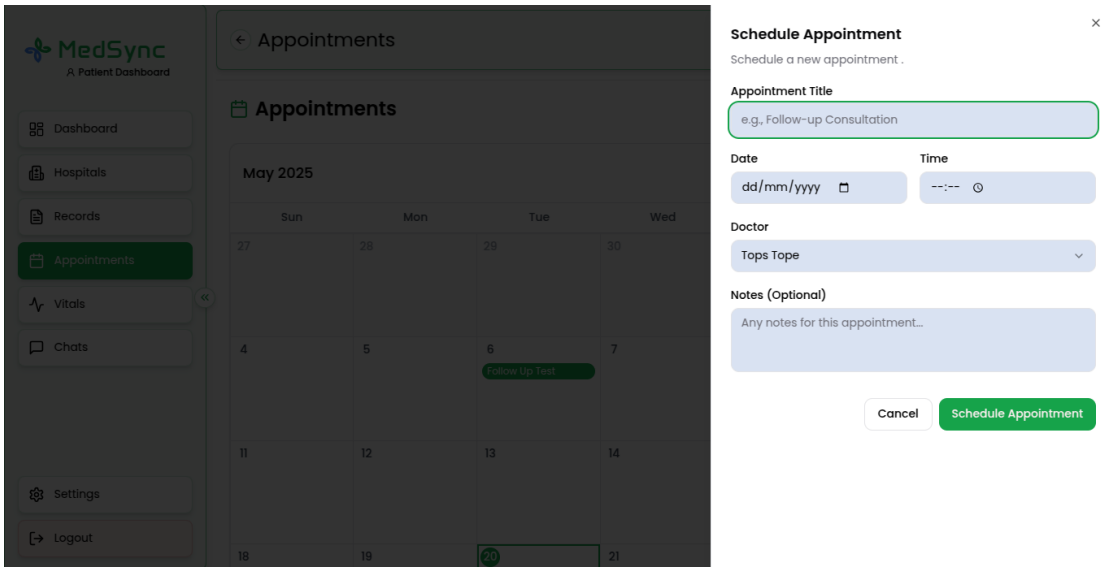


Figure 6: Appointment Scheduling Form

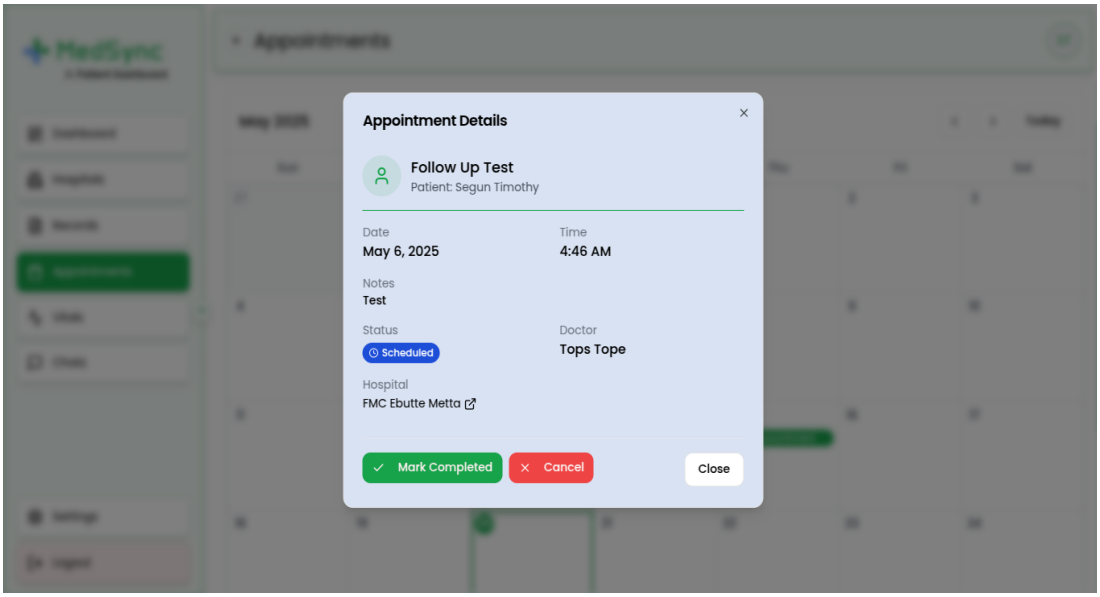


Figure 7: Appointment Details

Records Module

The Records module was the most complex to implement. Figures 9 through 12 present various user interface screens of this module, covering both patient and doctor views and illustrating how it functions as a comprehensive repository that captures each patient's healthcare journey across hospitals while maintaining clinical data in a secure and accessible manner.

The system organizes information chronologically from all connected hospitals. There are four types of records accounted for: Physician Notes, Test Advisories (Diagnostic Orders), Prescriptions, and Vital Signs.

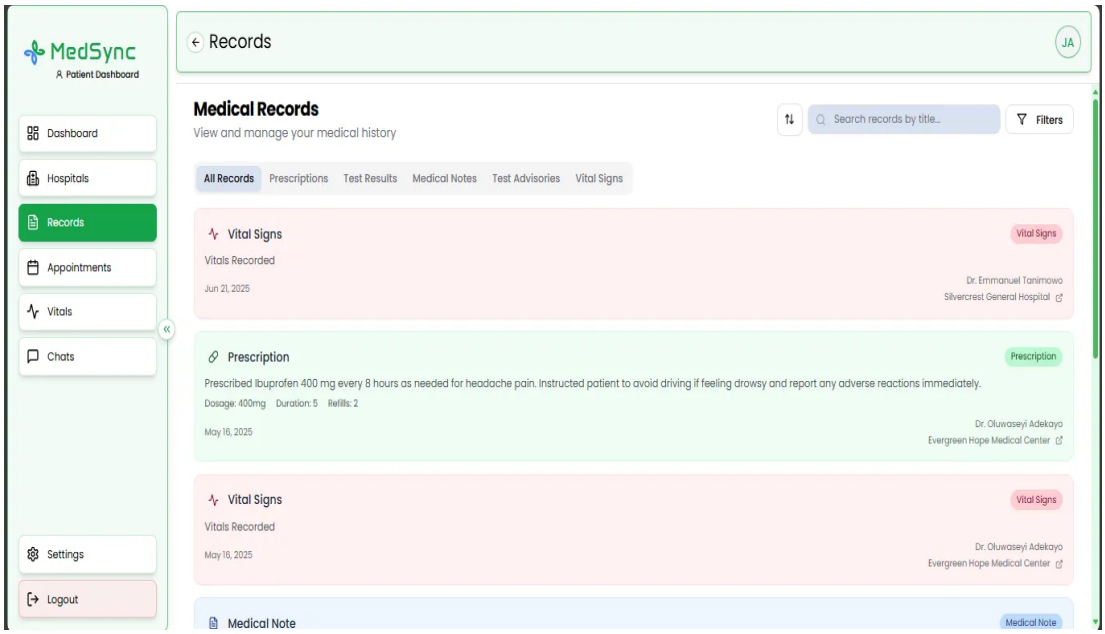


Figure 8: Patient View showing their medical history

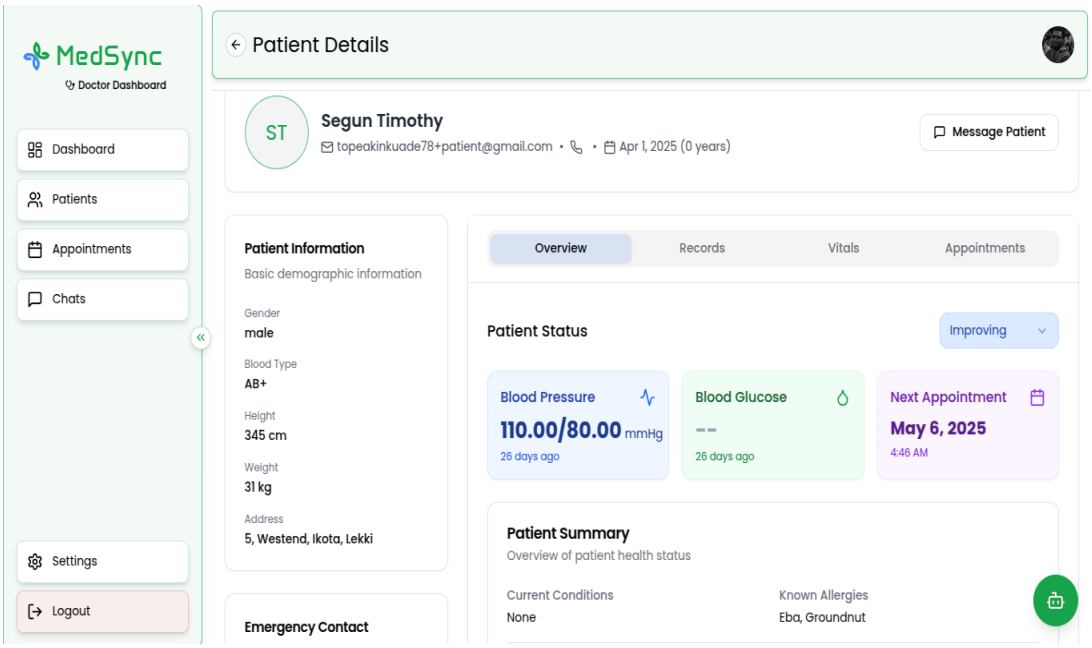


Figure 9: Doctor's view of a Patient Profile

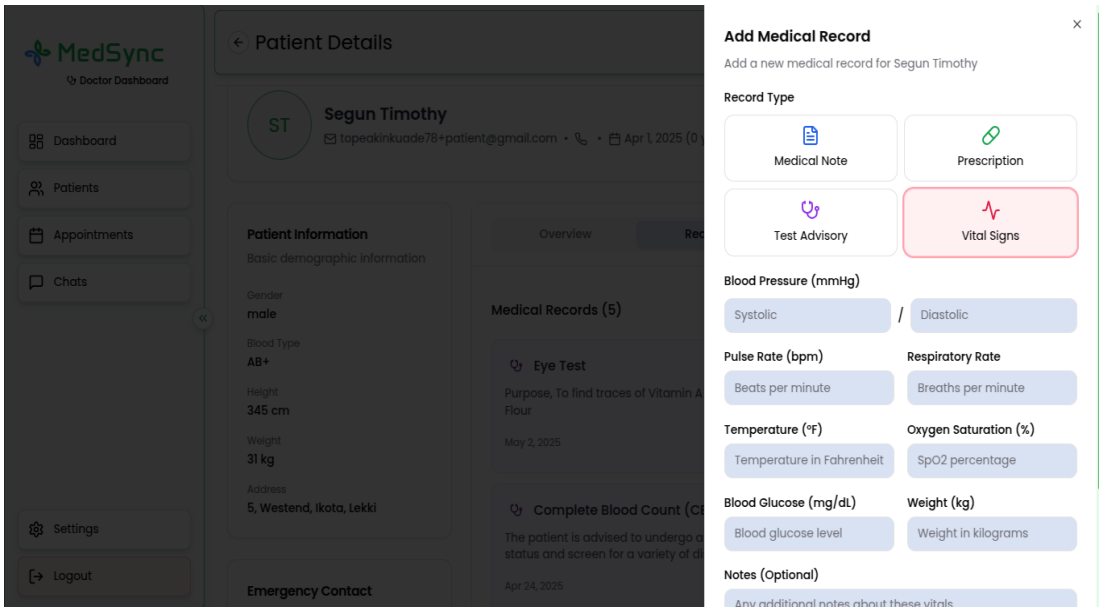


Figure 10: Doctor's view- Record Creation Form

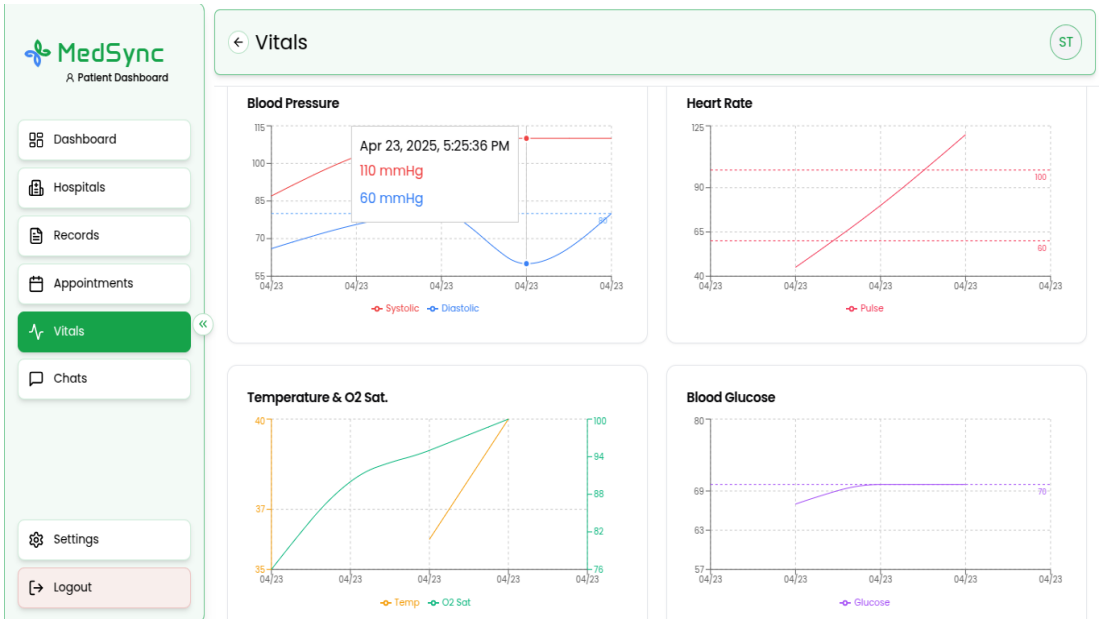


Figure 11: Patient Vitals Visualisation

Chats Module

Secure messaging addresses the communication gap between episodic visits, extending care relationships beyond physical encounters.

The chat module shown in Figure 13 below involves protected communication channels between providers and patients using WebSocket technology for real-time interaction. The system maintains complete conversation histories and uses JSON Web Token (JWT) authentication to securely manage sessions.

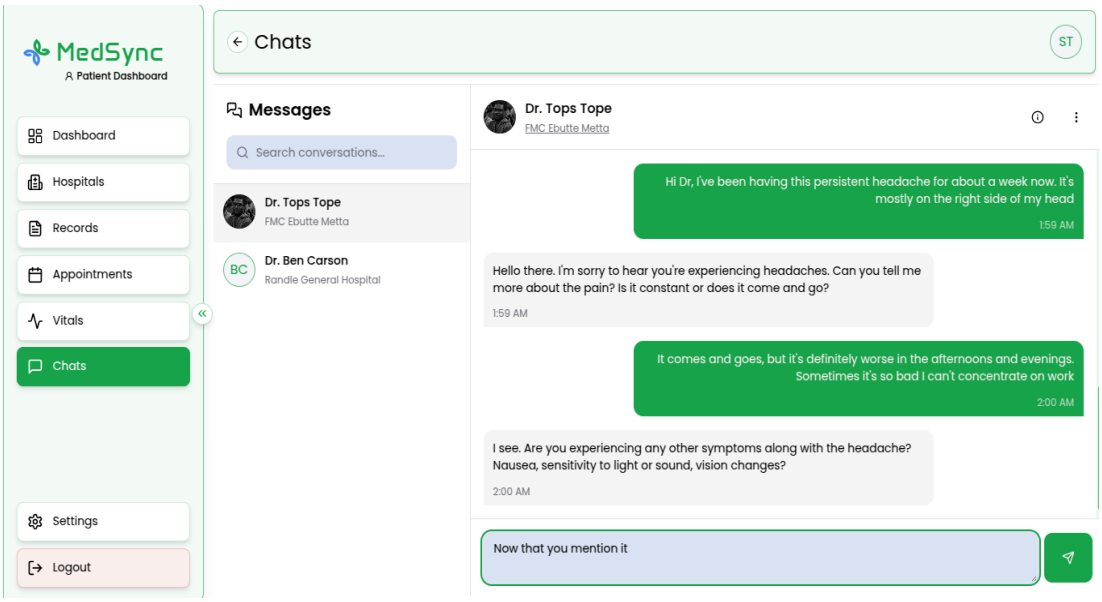


Figure 12: Doctor Patient Chats

AI Assistant Module

Powered by Gemini 2.5, the intelligent medical assistant augments doctors' capabilities through natural language interaction with clinical data.

As illustrated in Figure 14, its user interface seamlessly integrates within the clinical workspace, enabling physicians to generate structured summaries from notes, extract key clinical details from extensive documents, and access contextually relevant research literature aligned with each clinical scenario.

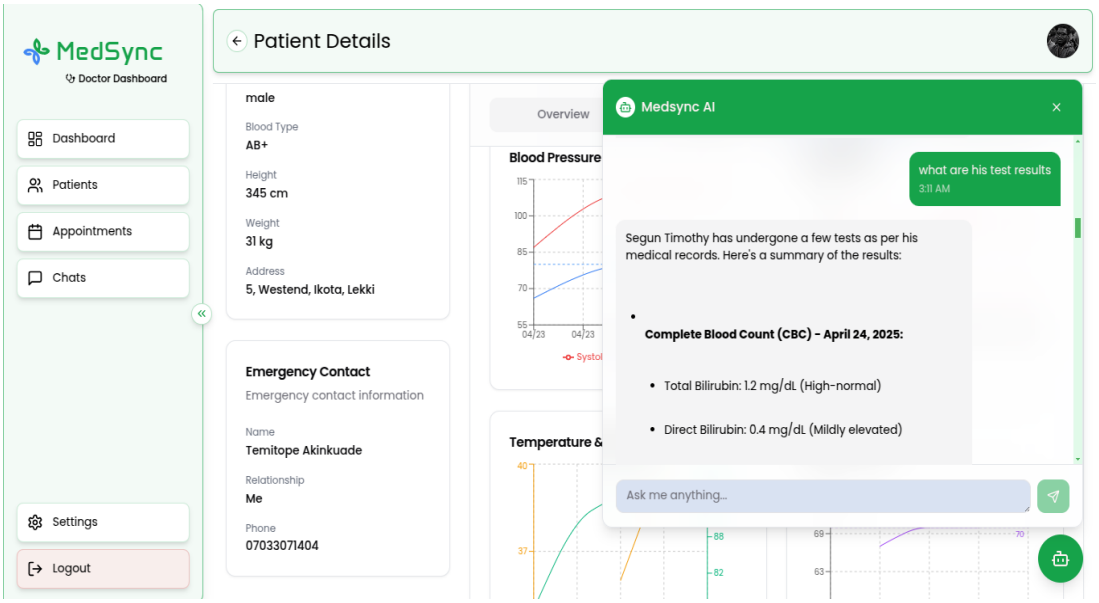


Figure 13: Context-aware Chatbot Assistant for doctors

CONCLUSION AND RECOMMENDATION

Reflecting on this journey, the creation of MedSync has been an illuminating confluence of technological rigor and contextual understanding. This reaffirms the view that innovative health information systems can overcome the infrastructural deficits endemic to developing nations through judicious design and the strategic use of modern technologies. The work lays a strong foundation for future advancements, nudging the country closer to a digitally integrated healthcare ecosystem.

While the prototype validates the core functionalities, several avenues for refinement beckon to amplify MedSync's efficacy and reach. Primarily, future iterations should incorporate FHIR (Fast Healthcare Interoperability Resources) standards to harmonize data exchange with international health systems.

Further, extending offline-first capabilities within the PWA would robustify access in Nigeria's variable network landscape, ensuring access to saved records during connectivity lapses. Privacy preservation could be bolstered by integrating encryption or block chain-based audit trails, elevating patient trust and compliance with evolving data protection statutes.

Engagement with stakeholders: patients, clinicians, and regulators must be deepened through iterative usability testing and feedback loops, guaranteeing that evolving system features resonate with real-world workflows and ethical imperatives. Lastly, scalability considerations warrant exploration of micro services architecture and container orchestration to sustain increasing loads without compromising responsiveness or security.

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