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Home Blood Sample Collection System: A Smart Health Portal for Home Diagnostics

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Abstract: The rapid advancement of digital healthcare technologies has significantly increased the demand for convenient, accessible, and efficient diagnostic services. Traditional blood testing methods require patients to physically visit diagnostic laboratories, leading to time consumption, inconvenience, overcrowding, and limited accessibility, especially for elderly individuals, working professionals, and patients in rural areas. This paper presents a Home Blood Sample Collection System, a smart health portal designed to streamline the process of booking blood tests, scheduling home sample collection, and delivering reports digitally. The proposed system integrates patients, laboratories, administrators, and phlebotomists through a centralized web-based platform, enabling seamless communication and efficient workflow management. It provides features such as online test selection, appointment scheduling, real-time tracking of sample collection, and secure digital report access, thereby eliminating manual processes and reducing human errors. The system ensures data privacy and reliability while improving transparency and user experience in diagnostic services. By reducing the need for hospital visits and enabling doorstep healthcare services, the platform enhances accessibility and operational efficiency. Furthermore, the system is scalable and can be extended with additional features such as online payment integration, teleconsultation, and advanced health analytics, making it a promising solution for modern digital healthcare ecosystems.

Keywords: Home Blood Sample Collection, Home Diagnostics, Healthcare System, Web Application, Telemedicine, Digital Health, Blood Test Booking, Report Management

I. INTRODUCTION

Diagnostic testing has long depended on patients physically visiting laboratories or healthcare centers—a model that, while effective in well-resourced settings, becomes inefficient where access to facilities is limited. Patients in rural areas or those seeking services during peak hours frequently encounter delays that affect timely diagnosis and treatment. Additionally, elderly individuals and patients with mobility constraints face significant challenges in accessing routine diagnostic services, highlighting the need for more accessible and efficient solutions.

Early digital solutions addressed parts of this problem through online booking systems and limited home sample collection services. However, these approaches remained restricted in scope and often operated independently. While booking systems could schedule appointments, they lacked real-time tracking, and collection services offered minimal integration with report delivery. As a result, the goal of a fully integrated diagnostic platform remains only partially achieved.

This work is undertaken to address that gap through the development of a **Home Blood Sample Collection System**, designed as a smart health portal for managing diagnostic services. The system integrates key functionalities into a single platform, enabling users to book tests, schedule home sample collection, and access reports digitally. The main contributions of this work are as follows: (1) the design of a unified platform connecting patients, laboratories, administrators, and phlebotomists; (2) the implementation of an automated workflow for test booking, sample collection, and report delivery; (3) a system architecture that ensures efficient data handling and secure access; and (4) an analysis of existing limitations and identification of areas for future improvement in home-based diagnostic services.

II. THEORETICAL BACKGROUND

Before examining individual system components, it is important to define the foundational framework that governs the operation of home diagnostic services.

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A. System Model

At the most general level, the home diagnostic system can be represented as a function that maps user inputs to diagnostic outputs through coordinated system processes:

$$R = f(U,S)$$

where U represents user inputs such as selected tests and appointment details, S denotes system components including scheduling, sample collection, and laboratory processing, and R is the generated diagnostic report. The system aims to efficiently transform input requests into reliable outputs.

B. Workflow Model

The overall diagnostic workflow consists of multiple sequential stages, which can be represented as:

$$W = \{B, A, C, L, R\}$$

where B is test booking, A is appointment scheduling, C is sample collection, L is laboratory processing, and R is report delivery. The efficiency of the system depends on smooth transitions between these stages.

C. Data Representation

User and diagnostic data can be modelled as a feature set:

$$D = (d1, d2, d3, \dots, dn)$$

where each d_i represents attributes such as user details, test parameters, or report values. Proper structuring of data ensures efficient storage and retrieval in the database.

D. Performance Metrics

System performance can be evaluated using efficiency metrics such as completion rate:

$$Efficiency = \frac{Completed\ Requests}{Total\ Requests}$$

This metric reflects how effectively the system processes user requests without delays or failures.

E. Response Time Model

The total system response time is composed of multiple components:

$$T = T_b + T_c + T_l + T_r$$

where T_b is booking time, T_c is collection time, T_l is laboratory processing time, and T_r is report delivery time. Minimizing total response time improves user experience.

F. Scalability Consideration

System scalability can be expressed in terms of handling user load:

$$Sc \propto N$$

where Sc represents system capacity and N is the number of users. A scalable system maintains performance even as user demand increases.

III. FOUR-TIER TAXONOMY

Reviewing existing home diagnostic solutions without a structured framework makes comparison difficult. We propose classifying home blood sample collection systems into four tiers, based on their functional depth and level of integration. The taxonomy is derived from practical system capabilities rather than theoretical assumptions, allowing clearer understanding of system evolution and limitations.

Tier 1: Basic Booking Systems

These represent the simplest level of functionality, where users can book diagnostic tests through an online interface. Such systems primarily handle appointment scheduling and basic user data management. While they improve

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accessibility compared to manual booking, they lack integration with sample collection tracking and report delivery. As a result, users must rely on external communication for updates, limiting overall system efficiency.

Tier 2: Sample Collection Coordination Systems

Tier 2 systems extend functionality by including home sample collection services. In addition to booking, these systems assign phlebotomists and manage scheduling for sample collection. This reduces the need for laboratory visits and improves user convenience. However, these systems often lack real-time tracking and seamless report integration, leading to partial automation and reliance on manual coordination.

Tier 3: Integrated Diagnostic Management Systems

At this level, systems provide a more comprehensive solution by integrating booking, sample collection, laboratory processing, and report delivery within a unified platform. Users can track appointments, receive notifications, and access reports digitally. These systems improve workflow efficiency and reduce delays, but may still face challenges related to scalability, real-time updates, and advanced data management.

Tier 4: Smart Health Portal Systems (Proposed)

The proposed system falls under this tier, representing a fully integrated and user-centric platform for home diagnostic services. It combines all functionalities—test booking, automated scheduling, phlebotomist assignment, real-time tracking, and digital report management—within a single interface. The system emphasizes seamless coordination between patients, laboratories, administrators, and phlebotomists, ensuring efficient workflow and improved user experience. Future enhancements may include teleconsultation, advanced analytics, and personalized healthcare recommendations, making it a scalable solution for modern digital healthcare ecosystems.

IV. LITERATURE REVIEW

The studies reviewed here were drawn from recent research on home-based blood sample collection and diagnostic systems, covering works published between 2021 and 2025. Selection criteria required that each study demonstrate practical implementation, usability evaluation, or clinical accuracy of home blood sampling techniques, with emphasis on experimental validation rather than purely descriptive analysis. Table I presents the full literature review summary.

TABLE I: LITERATURE REVIEW SUMMARY

Sl.	Author(s)	Year & Title	Method / Technique	Key Findings	Venue & Index
1	Lingervelder D. et al.	2025 – Validation of self-collected capillary blood	Comparative analysis of capillary vs venous samples	Achieved ~94% reliability for 15 analytes	Clinical Chemistry Lab Medicine
2	Morales A. et al.	2025 – Microsampling for SARS-CoV-2 testing	Capillary blood + saliva microsampling	High feasibility and accuracy in home testing	Frontiers in Public Health
3	Dasari H. et al.	2024 – Feasibility of self-blood collection	Usability study	Nearly painless and user-preferred method	BMC Primary Care

Sl.	Author(s)	Year & Title	Method / Technique	Key Findings	Venue & Index
4	Zarbl J. et al.	2024 – Remote upper-arm blood collection	Tasso+ / TAP II devices	~95% lab equivalence in results	RMD Open
5	Knitza J. et al.	2023 – Self-sampling accuracy study	Capillary sampling comparison	~98% correlation with lab results	Arthritis Research & Therapy
6	Smith J.A. et al.	2023 – Microsampling for metabolic panels	TAP II device testing	Enabled lipid & metabolic testing at home	Journal of Applied Lab Medicine
7	Mühlensiepen F. et al.	2022 – Patient perspective study	Qualitative analysis	High user satisfaction and acceptance	BMC Health Services Research

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8	Koulman A. et al.	2022 – Telehealth blood collection	OneDraw integration	Effective remote monitoring system	Journal Of Telemedicine
9	Cvetko A. et al.	2022 – Glycosylation analysis	Self-sampling validation	Comparable accuracy to clinical samples	BMC Research Notes
10	Hendelman T. et al.	2021 – Antibody testing	Tasso-SST device	Strong correlation with venous sampling	PLOS ONE

V. COMPARATIVE ANALYSIS

Several patterns emerge when the reviewed studies are examined collectively, revealing both strengths and limitations in current home diagnostic systems. Rather than analyzing each study individually, it is more useful to observe common trends across implementations. Most systems aim to improve accessibility and reduce the need for physical laboratory visits. This shift toward home-based diagnostics reflects the growing demand for convenience and patient-centered healthcare services. However, the level of integration and efficiency varies significantly across different approaches.

Home blood sample collection techniques demonstrate strong reliability in multiple studies, with accuracy levels typically ranging between 90% and 98% when compared to traditional venous sampling. Devices such as Tasso and TAP II have shown consistent performance and clinical validity. In addition to accuracy, usability studies highlight high patient acceptance, particularly due to reduced discomfort and ease of use. These features make home diagnostics especially beneficial for elderly patients and those with mobility constraints. Overall, the technological feasibility of home sampling has been well established.

Despite these advancements, most existing systems focus on individual components rather than complete workflow integration. Some systems support online booking, while others provide sample collection or report generation independently. However, the lack of real-time tracking and coordination between stakeholders limits overall system efficiency. This fragmented approach often leads to delays and reduced transparency in the diagnostic process. As a result, users may still depend on manual communication for updates and status tracking.

Furthermore, real-world implementation introduces challenges such as device cost, limited validation across diverse tests, and concerns related to data security and privacy. Many systems are not designed to handle large-scale deployment or high user demand effectively. These limitations highlight the need for a unified platform that integrates all aspects of the diagnostic workflow. The proposed system addresses these gaps by providing a comprehensive, scalable, and secure solution for home blood sample collection and management.

In addition to these challenges, variability in system design and implementation standards further affects the consistency of home diagnostic services. Different platforms adopt varying approaches for scheduling, data management, and communication, leading to differences in user experience and system reliability. The absence of standardized protocols for integrating laboratory operations with digital platforms creates inefficiencies and potential errors in workflow execution. Addressing these issues requires the development of standardized, well-integrated solutions that ensure consistency and scalability across home-based diagnostic systems.

TABLE II: COMPARATIVE ANALYSIS OF REVIEWED SYSTEMS

Sl.	Paper	Protocol / Technique	Performance	Advantages	Limitations
1	Lingervelder et al.	Capillary vs venous comparison	High (~94%)	Reliable alternative to lab sampling	Limited to chemistry analytes
2	Morales et al.	Microsampling (blood + saliva)	Moderate–High	Suitable for home-based testing	Focused on viral serology
3	Dasari et al.	Capillary self-sampling usability	High	Painless and user-friendly	Not tested for complex diagnostics
4	Zarbl et al.	Upper-arm devices (Tasso+/TAP II)	High (~95%)	High lab equivalence	Device cost and sensitivity issues

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5	Knitza et al.	Autoantibody testing (self vs lab)	High (~98%)	Strong correlation with lab results	Limited to specific disease
6	Smith et al.	TAP II microsampling device	High	Enables lipid & metabolic testing	Limited biomarker scope
7	Mühlensiepen et al.	Qualitative usability study	Moderate	High patient acceptance	No quantitative metrics
8	Koulman et al.	Telehealth + remote sampling	High	Supports remote monitoring	No long-term validation
9	Cvetko et al.	Glycosylation analysis	High	Comparable to clinical samples	Niche application
10	Hendelman et al.	Tasso-SST antibody testing	High	Accurate remote testing	Limited to antibodies

VI. RESEARCH GAP

The review of existing home blood sample collection systems reveals several consistent limitations across the studied works. The following gaps are identified based on analysis of current methodologies and system implementations.

Gap 1 — No Fully Integrated Platform:
Most existing systems focus on individual components such as sample collection devices or laboratory validation. There is no single platform that integrates booking, sample collection, tracking, and report delivery in a unified system.

Gap 2 — Lack of Real-Time Tracking:
Current systems do not provide effective real-time tracking of sample collection or phlebotomist movement. Users often depend on manual communication, which reduces transparency and efficiency.

Gap 3 — Limited Workflow Automation:
Many solutions rely on semi-manual processes for scheduling, assignment, and report management. This leads to delays and increases the chances of human error in the diagnostic workflow.

Gap 4 — Data Management and Security Issues:
Handling sensitive patient data requires secure storage and controlled access. Several systems lack proper mechanisms for data protection, role-based access, and secure report sharing.

Gap 5 — Scalability Constraints:
Most systems are designed for limited use and are not optimized for large-scale deployment. Handling multiple users, laboratories, and real-time operations remains a challenge.

Gap 6 — Lack of Standardization:
Different systems follow different protocols for sample handling, scheduling, and reporting. This lack of standardization leads to inconsistencies in service quality and user experience.

Gap 7 — Accessibility Limitations:
Many platforms assume users have good internet access and digital literacy. Rural users, elderly patients, and non-technical users may face difficulties in using these systems effectively.

VII. CONCLUSION

This work examined the current landscape of diagnostic service systems with a focus on accessibility, efficiency, and integration. Existing approaches such as laboratory-based testing, online booking portals, and partial home collection services have improved specific aspects of healthcare delivery, but they remain fragmented in practice. Most systems address isolated functionalities such as scheduling or report generation, without providing a seamless end-to-end workflow for patients and healthcare providers.

At the same time, this study highlights a clear gap in fully integrated home diagnostic platforms. No single system combines test booking, home sample collection, real-time tracking, and digital report management within a unified interface. The proposed Home Blood Sample Collection System addresses this gap by integrating these functionalities

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into a single platform, ensuring improved coordination between patients, laboratories, and phlebotomists. The system enhances user convenience, reduces operational delays, and improves transparency in diagnostic processes.

The findings suggest that future research should focus not only on improving individual components but also on system-level integration and scalability. Key areas for further development include secure data handling, real-time workflow optimization, and support for diverse user groups, including rural populations. With proper implementation, such systems can significantly contribute to modernizing healthcare delivery and making diagnostic services more accessible and efficient.

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