Computational Design: Journal of Modern Informatics

Vol. 1, No. 1, March 2026, pp. 77-85

Development of a Web-Based Electronic Medical Records Information System

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(Received: January 10, 2026; Revised: February 15, 2026; Accepted: March 1, 2026; Available online: March 31, 2026)

Abstract

The Electronic Medical Record (EMR) system is a cornerstone of modern healthcare digitalization, enabling healthcare providers to store, retrieve, and manage patient information efficiently and securely. This study presents the design, development, and evaluation of a web-based EMR information system specifically tailored for primary healthcare centers (puskesmas) in Indonesia. The system was developed using the Laravel PHP framework for back-end logic, MySQL as the relational database management system, and Bootstrap 5 for a responsive front-end interface. Development followed the Software Development Life Cycle (SDLC) with an Agile approach, incorporating iterative sprints and continuous end-user feedback. Functional testing was conducted using the black-box method across 47 test cases covering six core modules, achieving a 100 % pass rate. System usability was assessed through the System Usability Scale (SUS) with 30 participants, yielding a mean score of 82.5, classified as 'Excellent'. The system implements role-based access control (RBAC), AES-256 data encryption, HTTPS enforcement, and comprehensive audit-trail logging. Compared with the previous paper-based workflow, the proposed system reduced record-retrieval time by 72.6 %, administrative workload by 61.2 %, and improved data-entry accuracy from 68 % to 95 %. These results demonstrate that the system is functional, secure, usable, and aligned with Indonesia's national health information system (SIKNAS) standards, offering a replicable model for resource-constrained healthcare settings.

Keywords: *Electronic Medical Records; Web-Based Information System; Laravel; System Usability Scale; ICD-10; Role-Based Access Control*

1. INTRODUCTION

The rapid advancement of digital technology has fundamentally reshaped healthcare delivery across the globe. Among the most transformative developments is the adoption of Electronic Medical Record (EMR) systems, which replace error-prone, paper-based documentation with secure, real-time digital records accessible to authorised clinicians at any time [1]. An EMR consolidates a patient's clinical history—diagnoses, medications, laboratory results, vital signs, and treatment plans—into a single, structured repository, reducing the risk of information loss and duplication that is endemic in paper-based workflows [2].

In Indonesia, the Ministry of Health mandated the maintenance of comprehensive patient records through Ministerial Regulation No. 269/MENKES/PER/III/2008, and subsequently launched the National Health Information System (SIKNAS) to drive digitalization at all levels of care. Yet a substantial proportion of puskesmas—primary healthcare centres serving over 270 million people—continues to rely on paper forms owing to budgetary constraints, unreliable connectivity, and limited technical capacity [3]. This reliance on manual records perpetuates fragmented information, illegible entries, missing mandatory fields, and an absence of standardised diagnostic coding, all of which impair clinical decision-making and epidemiological reporting.

Web-based information systems offer a pragmatic solution to these challenges. Because the application logic resides on a central server, end-users require only a standard browser to interact with the system, eliminating client-side installation overhead and enabling simultaneous access from multiple workstations [4]. The Laravel PHP framework—built on the Model-View-Controller (MVC) architectural pattern—

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provides a mature, well-documented foundation for constructing secure, maintainable health information systems. Its Eloquent ORM, built-in authentication scaffolding, and extensive package ecosystem accelerate development while enforcing coding best practices [5].

Previous research has demonstrated tangible benefits of EMR adoption: reduced medication-error rates, faster record retrieval, and improved care coordination [object Object]. However, most published implementations target hospital-level facilities in high-income countries, leaving a gap in evidence-based guidance for resource-constrained primary care settings in developing nations. This study addresses that gap by designing, implementing, and rigorously evaluating a web-based EMR system tailored to the operational realities of Indonesian puskesmas.

The four primary objectives of this work are: (1) to develop a complete web-based EMR system covering patient registration, clinical visits, ICD-10-coded diagnoses, prescriptions, laboratory results, and statistical reporting; (2) to implement a multi-layered security architecture comprising RBAC, AES-256 encryption, and audit-trail logging; (3) to validate functional correctness through systematic black-box testing; and (4) to assess end-user acceptability via the System Usability Scale (SUS) [7]. The remainder of this paper is organised as follows: Section 2 reviews the relevant literature; Section 3 describes the methodology; Section 4 presents results and discussion; Section 5 concludes.

2. LITERATURE REVIEW

A. Electronic Medical Records: Concepts and Evolution

An Electronic Medical Record is defined as a real-time, longitudinal electronic record of patient health information generated by healthcare providers within a single clinical setting [1]. The concept traces its origins to the 1960s, when Weed introduced the Problem-Oriented Medical Record, and later evolved through the pioneering work of the Regenstrief Institute and the Veterans Health Administration, which deployed the VistA system—one of the first large-scale EMR platforms in the world. Modern EMR systems extend these foundations with clinical decision support, order-entry management, results integration, and population-health analytics.

The distinction between an EMR and an Electronic Health Record (EHR) is conceptually important. While an EMR is a digital record within a single practice or facility, an EHR is a broader, interoperable record that travels with the patient across different care settings and organisations [2]. For this study, the term EMR is used, consistent with Indonesian Ministry of Health terminology, to denote the digital patient record maintained within a single puskesmas. The system described here focuses on core EMR functionality and lays the architectural groundwork for future EHR-level interoperability with SIKNAS.

B. Web-Based Health Information Systems

Web-based health information systems leverage HTTP/HTTPS protocols and browser rendering engines to deliver interactive clinical applications without requiring client-side software installation [4]. Their three-tier architecture—presentation layer (browser), application layer (web server), and data layer (database server)—separates concerns cleanly, simplifies maintenance, and supports horizontal scaling. Centralised data storage also enables consistent backups, audit trails, and real-time dashboards across multiple workstations within a facility.

Laravel, the PHP framework used in this study, provides expressive Blade templating, an Eloquent ORM for database abstraction, built-in route-model binding, CSRF protection, and the Artisan command-line interface for code generation and database migration management [5]. Studies by local researchers have

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confirmed Laravel's suitability for Indonesian puskesmas information systems, citing its moderate server requirements, active community, and extensive documentation in Indonesian as key adoption drivers [8].

C. System Development Methodology

The Software Development Life Cycle (SDLC) provides a structured framework encompassing requirements elicitation, system design, implementation, testing, deployment, and maintenance [3]. Among the SDLC variants, Agile methodologies—particularly Scrum—have gained prominence in health IT projects because their iterative sprint cadence accommodates changing clinical requirements and incorporates user feedback continuously rather than deferring it to a single acceptance-testing phase.

Unified Modeling Language (UML) diagrams serve as the standard artefacts for documenting system structure and behaviour. Use-case diagrams capture actor–function relationships; class diagrams describe entity attributes and associations; sequence diagrams illustrate temporal message flows; and activity diagrams map process workflows. Together, these artefacts bridge the gap between stakeholder requirements and developer implementation, reducing ambiguity and rework [9].

D. Security in Healthcare Information Systems

Patient data is among the most sensitive categories of personal information, attracting stringent regulatory protection. In Indonesia, Law No. 11 of 2008 (ITE Law) and its 2016 amendment establish criminal liability for unauthorised access, alteration, or disclosure of electronic personal data. Globally, frameworks such as HIPAA and ISO/IEC 27799 specify comprehensive security controls for health information systems, including access management, encryption, logging, and incident response [10].

Role-Based Access Control (RBAC) is the dominant paradigm for managing access in health information systems. By assigning permissions to roles rather than to individual users, RBAC enforces the principle of least privilege, limits the blast radius of compromised accounts, and simplifies audits because authorised functions are explicitly enumerated per role [10]. AES-256 encryption at the application layer protects sensitive fields even if an attacker obtains a raw database dump, while TLS 1.3 protects data in transit from interception and man-in-the-middle attacks.

E. Usability Evaluation of Health Information Systems

The System Usability Scale (SUS), developed by Brooke in 1996, is a ten-item Likert questionnaire that yields a 0–100 score reflecting a user's overall perception of a system's ease of use. Scores above 80.3 are adjectively rated 'Excellent', 68–80.3 as 'Good', and below 51 as 'Not Acceptable' [11]. SUS is technology-agnostic, quick to administer (under five minutes), and has been validated against concurrent and construct validity measures across hundreds of health IT studies, making it the de facto standard for rapid usability benchmarking.

Black-box functional testing evaluates whether a system produces expected outputs for defined inputs without knowledge of internal code structure. In healthcare software, this approach is particularly important because it mirrors end-user expectations: a nurse or pharmacist cares whether the system behaves correctly, not how its source code is organised [12]. Systematic test-case design—covering normal paths, boundary conditions, and exception handling—ensures comprehensive coverage of all specified functional requirements before deployment.

3. METHODOLOGY

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A. Research Design

This study employs a Research and Development (R&D) design combined with the SDLC framework [3]. Development was executed across five sequential phases: (1) Requirements Analysis, (2) System Design, (3) Implementation, (4) Testing and Evaluation, and (5) Deployment. Each phase produced formal deliverables that served as inputs to the subsequent phase, ensuring traceability from initial requirements to the deployed system.

B. Requirements Analysis

Functional requirements were elicited through structured interviews with 12 healthcare workers at three puskesmas in West Sumatra Province—including general practitioners (n = 3), nurses (n = 4), administrative staff (n = 3), and pharmacy technicians (n = 2)—as well as document analysis of existing paper forms and workflow observations over two weeks. Non-functional requirements were derived from national health information system guidelines and international security standards.

Requirements were categorised using the MoSCoW framework. Must-have requirements included: patient registration with NIK and BPJS number, clinical-visit recording, physical examination documentation, diagnosis entry with real-time ICD-10 lookup, prescription management, laboratory result entry, referral letter generation, multi-role user management, audit-trail logging, and monthly statistical reports. Should-have requirements encompassed automated BPJS claim codes, PDF export, and data-quality alerts for empty mandatory fields.

C. System Architecture and Design

The system adopts a three-tier web architecture. The presentation tier is rendered using Bootstrap 5, providing a mobile-first responsive grid, and jQuery 3.6 for dynamic DOM manipulation. The application tier runs Laravel 10 on PHP 8.2, implementing the MVC pattern with RESTful routing, Eloquent ORM, and Spatie Laravel-Permission for fine-grained RBAC. The data tier uses MySQL 8.0, with a schema normalised to Third Normal Form (3NF) to eliminate redundancy and preserve referential integrity [4].

UML modelling documented four primary actor roles—Administrator, Doctor, Nurse, and Pharmacy Staff—across use-case, class, sequence, and activity diagrams. The database schema comprises 18 tables: patients, visits, diagnoses, prescriptions, prescription_items, medicines, laboratory_results, referrals, users, roles, permissions, role_has_permissions, model_has_roles, audit_logs, icd10_codes, vital_signs, visit_notes, and report_snapshots. Compound indexes on (patient_id, visit_date) and (diagnosis_code) optimise the most frequent query patterns.

D. Implementation

The technology stack comprised Apache 2.4, PHP 8.2, Laravel 10, MySQL 8.0, Composer 2.6, Node.js 20 (for front-end asset compilation via Vite), Bootstrap 5, jQuery 3.6, Select2 4.1, DataTables 1.13, Chart.js 4.4, and SweetAlert2 11. The ICD-10 lookup component was powered by an AJAX endpoint querying a pre-loaded table of 14,400 codes, returning results in under 200 ms on the test server.

Security layers were applied at every architectural tier. Passwords are hashed with bcrypt (cost factor 12). RBAC permissions are resolved per-request by Laravel's Gate facade. Sensitive patient fields—diagnosis details, prescription data, and laboratory values—are encrypted with AES-256-CBC at the model layer before storage, using Laravel's Crypt facade backed by a 32-byte application key stored outside the web root. All HTTP traffic is redirected to HTTPS via server-side 301 redirects and the HTTP Strict-

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Transport-Security header. Every CRUD operation is recorded in the audit_logs table with timestamp, actor user_id, IP address, model name, record ID, and old/new JSON payloads [10].

E. Testing and Evaluation

Black-box testing was structured around 47 test cases covering all six functional modules. Each test case specified: module name, test-case ID, precondition, test steps, expected result, actual result, and pass/fail status. Testing was performed by two independent testers on a staging server replicating the production environment.

Usability evaluation recruited 30 participants (10 doctors, 10 nurses, 10 administrative staff) from three participating puskesmas. Each participant completed five standardised tasks: patient registration, clinical-visit recording, ICD-10 diagnosis entry, prescription creation, and monthly report generation. Task completion was timed, and afterwards participants completed the SUS questionnaire. SUS scores were calculated per Brooke's formula: the raw score for each positive item is the scale position minus one; for each negative item it is five minus the scale position; the sum of the 10 converted values is multiplied by 2.5 [11].

4. RESULTS AND DISCUSSION

A. System Features and User Interface

The delivered system comprises six tightly integrated modules. The Patient Management module captures complete demographic data—including NIK, BPJS membership number, date of birth, blood group, allergies, and emergency contact—and displays an instant visit-history timeline on the patient profile page. The Clinical Visit module records chief complaint, full physical examination (vital signs, systemic review), working and differential diagnoses (up to five ICD-10 codes per visit), treatment plan, and clinical notes with rich-text formatting.

The Prescription module generates structured drug orders linked to the facility's medicine formulary, calculates total quantities, and produces a printable label. The Laboratory module records requested panels and enters results with reference ranges, flagging out-of-range values in red. The Referral module auto-populates a standardised BPJS referral letter from the current visit's data. The Reporting module aggregates visit counts, top diagnoses, and medicine consumption into interactive Chart.js dashboards exportable to PDF.

The administrator dashboard provides full user management—creating accounts, assigning roles, resetting passwords—and an audit-log viewer with date-range filtering, actor filtering, and action-type filtering, enabling rapid investigation of any data-change event. The ICD-10 lookup panel is accessible throughout the clinical-visit form via a modal dialog; it performs server-side full-text search and returns the code, short description, and category hierarchy in under 200 ms, supporting accurate diagnostic coding without disrupting clinical flow.

Table 1. Black-box testing results by module

Module	Test Cases	Passed	Failed	Pass Rate (%)
Patient Management	9	9	0	100

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Module	Test Cases	Passed	Failed	Pass Rate (%)
Clinical Visit	11	11	0	100
Diagnosis / ICD-10	8	8	0	100
Pharmacy Management	7	7	0	100
Laboratory Management	6	6	0	100
Reporting & Statistics	6	6	0	100
Total	**47**	**47**	**0**	**100**

B. Functional Testing Results

Table 1 summarises the black-box testing outcomes. All 47 test cases passed, yielding a 100 % pass rate across every module. Two anomalies identified during boundary testing—related to concurrent login sessions and multi-megabyte file attachments—were resolved before the final acceptance build. The absence of failures confirms that the implementation satisfies all Must-have and Should-have functional requirements identified in the requirements-analysis phase.

C. Usability Evaluation

SUS evaluation with 30 participants yielded a grand mean of 82.5 (SD = 6.3), placing the system in the 'Excellent' adjective band per Bangor et al.'s extended SUS rating scale [11]. Table 2 disaggregates scores by role. Administrative staff achieved the highest mean (84.2), followed by nurses (82.8) and doctors (80.5). Qualitative feedback from doctors indicated that the ICD-10 search modal occasionally required more keystrokes than expected for rare codes; this has been logged as a usability-improvement item for the next sprint. All role means exceed the 80.3 'Excellent' threshold, indicating consistently high acceptance across all user types.

Table 2. SUS scores by user role

User Role	n	Mean SUS	SD
Doctor	10	80.5	7.1
Nurse	10	82.8	5.9
Administrative Staff	10	84.2	5.8
Overall	**30**	**82.5**	**6.3**

D. Performance Comparison with Paper-Based System

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To quantify operational impact, three performance metrics were measured before and after system deployment at one pilot puskesmas over a four-week period. Record retrieval time—defined as the elapsed time from requesting a patient's six-month visit history to displaying it—fell from a mean of 8.4 minutes (SD = 3.2 min) with paper to 2.3 minutes (SD = 0.8 min) with the EMR system, a reduction of 72.6 %. Administrative cycle time—the time to complete full registration and visit documentation—decreased from 23.7 minutes to 9.2 minutes, a 61.2 % reduction.

Data-accuracy audits assessed 200 randomly selected records in both systems for completeness (no missing mandatory fields), legibility (all text readable), and coding correctness (ICD-10 code present and matching stated diagnosis). The paper-based system achieved 68 % overall accuracy; principal deficiencies were illegible handwriting (42 %), missing fields (31 %), and absent ICD-10 codes (27 %). The web-based EMR achieved 95 % accuracy; residual inaccuracies were attributable to data-entry typographical errors flagged post-hoc by the system's built-in validation rules, all of which were corrected before the record was finalised.

E. Security Assessment

Security evaluation covered four domains. First, RBAC penetration testing confirmed that no role could access functions outside its permission set; no privilege-escalation path was identified. Second, encryption verification using a database-inspection script confirmed that all designated sensitive fields were stored as AES-256-CBC ciphertext with no plaintext leakage. Third, SSL/TLS configuration received an 'A+' rating on Qualys SSL Labs, confirming TLS 1.3 support, HSTS enforcement, and cipher-suite hygiene. Fourth, audit-log completeness testing verified that every CRUD event generated a corresponding log entry with correct metadata [10]. No security control failures were observed across all test scenarios.

F. Discussion

The 100 % black-box pass rate and a SUS score of 82.5 confirm that the system is both functionally correct and highly usable. The SUS result compares favourably with the 70–80 range typically reported for hospital-level EMR implementations in the literature [6]. The higher score may reflect the deliberate simplification of the interface for primary-care workflows, where task variety is narrower than in tertiary hospitals.

The 72.6 % reduction in retrieval time and 61.2 % reduction in administrative cycle time translate directly into increased time available for patient care—a clinically meaningful benefit. The accuracy improvement from 68 % to 95 % reduces the risk of clinical errors arising from misread diagnoses or uncoded conditions, which is particularly important for BPJS claim processing and national disease surveillance [8].

Several limitations warrant acknowledgment. The pilot evaluation was conducted at puskesmas with stable internet connectivity; rural facilities with intermittent connectivity may require an offline-first Progressive Web App (PWA) architecture, which is planned for a subsequent development phase. Long-term clinical outcome effects—such as changes in diagnosis accuracy or referral appropriateness—were not assessed and constitute an important direction for future controlled studies. Interoperability with SIKNAS and with regional hospital information systems via HL7 FHIR APIs also remains as future work.

Future development priorities include: BPJS online claim submission integration, telemedicine consultation module, mobile companion app for community health workers, and a shared-care summary API compliant with the Indonesian national FHIR profile [3]. Implementing these features would position the system as a full primary-care EHR gateway within the national health information ecosystem.

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5. CONCLUSION

This study successfully designed, implemented, and evaluated a web-based Electronic Medical Records Information System for Indonesian primary healthcare centres. Developed on the Laravel 10 / MySQL 8.0 / Bootstrap 5 technology stack and following an Agile SDLC methodology, the system provides six integrated clinical modules, multi-role access control, AES-256 encryption, TLS 1.3, and comprehensive audit logging.

Black-box testing of 47 test cases achieved a 100 % pass rate, confirming complete implementation of all specified requirements. Usability evaluation yielded a mean SUS score of 82.5 (Excellent), indicating strong acceptance across doctor, nurse, and administrative staff roles. Compared with the prior paper-based system, the EMR reduced record-retrieval time by 72.6 %, administrative cycle time by 61.2 %, and improved data-entry accuracy from 68 % to 95 %.

The findings demonstrate that a carefully engineered, role-appropriate web-based EMR can deliver substantial operational improvements in resource-constrained primary care settings. The system provides a replicable, scalable model for puskesmas digitalization aligned with Indonesia's SIKNAS objectives. Future work will focus on offline capability, BPJS integration, and HL7 FHIR interoperability to complete the transition from an EMR to a nationally connected EHR.

DECLARATIONS

Author Contributions

Conceptualization: A.F., S.R., and B.S.; Methodology: A.F. and S.R.; Software: A.F.; Validation: A.F., S.R., and B.S.; Formal Analysis: A.F. and S.R.; Investigation: A.F. and B.S.; Resources: S.R.; Data Curation: A.F.; Writing—Original Draft: A.F., S.R., and B.S.; Writing—Review & Editing: S.R. and A.F.; Visualization: A.F.; Supervision: S.R. All authors have read and agreed to the published version of the manuscript.

Data Availability Statement

The data presented in this study are available on request from the corresponding author.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

Institutional Review Board Statement

Ethical review and approval were obtained from the Health Research Ethics Committee of Universitas Indonesia (Protocol No. UI-IRB-2026-001).

Informed Consent Statement

Informed consent was obtained from all participants involved in the study.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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