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# Design and Implementation of Maternal Risk and Death Reporting System

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#### KeyWords

Maternal health, MPDSR, maternal risk reporting, maternal death audit, role-based access control, mobile health system, Nigeria.

#### ABSTRACT

In Nigeria, maternal and perinatal mortality are a significant issue in the public health, which is further complicated by the poor integration between reporting, reviewing, and responding systems, as well as the fragmented and paper-based nature of such surveillance. This research conceived and put into place a Maternal Risk and Death Reporting System to help facilitate organized, mobile-enhanced workflows of maternal and perinatal mortality surveillance and response in low-resource locations. It was created as a modular web and mobile solution that employs role-based access control, secure data management, automated alerts, and standardized maternal and perinatal death classification which is in compliance with international standards. The structure was in a layered client-server architecture that isolated user interfaces, backend services and data storage to be maintainable and scalable. Scenario-based simulation and functional testing demonstrated that the system has the ability to record maternal risk factors, activate alerts on high-risk cases, facilitate structured audit documentation, as well as implement access controls across user domains. The research offers a scalable technical basis to enhance maternal surveillance processes and accountability, and it assists in pilot implementation and expansion in the future.

## Introduction

Maternal and perinatal mortality continue to be urgent public health issues in the low- and middle-income countries (LMICs), with Nigeria contributing a disproportionately large part of maternal deaths in the world [4], [8], [16], [17]. Although the tools to support and guide efficient surveillance-to-response are available in terms of clinical guidelines and maternal and perinatal death surveillance and response (MPDSR) frameworks, in numerous health facilities with the resources constraint, the tools still depend on the disjointed, paper-based system of reporting, which hinders the promptness of the notification of cases, erodes accountability, and restricts efficiency of the surveillance-to-response processes [4], [5], [8]. Such restrictions compromise the opportunity to intervene in time, diminish the discernibility of new risk trends, and decrease the accuracy of national statistics on maternal health [6], [16], [18].

The current maternal surveillance procedures in Nigeria and other similar LMIC settings can be described as follows: delayed reports, inconsistent data collection, inadequate community level reporting to facility level reporting and central review procedures [5], [6], [8]. Hand-based data collection implies transcription faults, documented information losses, and extended reporting delays, and the lack of automated risk identification restricts the timely identification of high-risk pregnancies [6], [17]. Moreover, numerous digital health interventions implemented in such settings have weak interoperability, role-based access control, and lack of support to document structured maternal deaths audit [1], [19], [20]. It has also been empirically demonstrated that disjointed digital tools, overlapping reporting, and poor data-to-action connections still undermine MPDSR performance in humanitarian and low-resource health systems [4], [5], [16].

To fill these gaps, the current study developed and deployed a Maternal Risk and Death Reporting System (MRDRS) that will help to support the structured and mobile-enabled MPDSR workflows. This system incorporates real-time data capture, automated risk warning, secure role-based access control, and standardized maternal and perinatal deaths categorization in accordance with the international standards [1], [4], [17]. The architecture that was implemented was a layered clientserver architecture, in order to decouple user interfaces, backend services, and data storage, thus enhancing maintainability, scalability, and deployment flexibility on low-resource settings [21], [22], [23]. The design of the platform was also guided by evidence regarding the culturally sensitive development of mHealth, usability limitations in the LMIC context, and iterative design practices, which are user-centered [2], [7], [9], [11], [12].

This study was aimed at creating a practical reporting system, which can record maternal risk factors and death incidents, impose access controls among various user groups, issue automated notifications on high-risk patients, and facilitate systematic audit reports of maternal and perinatal mortality [1], [6], [17]. Functional testing and scenario-based simulation were used to test the system to determine its capabilities to support timely reporting, maintain data integrity, and enhance the accountability of workflows in the decentralized care environment [6], [19], [20].

This study has three-fold contributions. First, it introduces a viable system architecture model of the deployment of a mobile-enabled maternal risk and death reporting system under resource-restricted settings [21], [22], [23]. Second, it shows that automated risk flagging and role-based workflows can be incorporated into maternal surveillance procedures to enhance the early detection, accountability, and data-to-action responsiveness [1], [6], [17], [18]. Third, it offers an implementation roadmap, which can be extended to pilot implementation and national MPDSR implementation, overcoming the interoperability, usability, and data quality issues observed in current digital maternal health systems [4], [5], [16], [19], [20].

## Related Works

There has been a growing interest in digitizing health toward enhancing maternal and perinatal death surveillance and response (MPDSR) processes in low- and middle-income countries (LMICs). Various researches have indicated that mobile-enabled reporting systems can minimize delays on case notification, enhance data completeness, and coordination in the interaction between community health workers and health facilities [4], [5], [6], [8]. It has been shown that digital MPDSR systems facilitate real-time dashboards, trend analysis, and identify causes, but it continues to experience challenges in under-reporting, inconsistent reviews of cases, and weak correlations in between data and actions [6], [8], [16]. These results highlight the utility of digital maternal surveillance implementation and the systemic constraints of current digital maternal surveillance implementations.

To facilitate real-time reporting of maternal deaths and pregnancy outcomes, mobile health (mHealth) systems of maternal surveillance have been implemented in a range of resource-restricted contexts. Previous research has shown that short message service (SMS)-based reporting tools and mobile applications-based reporting tools can drastically decrease the reporting latency relative to paper-based systems and enhance engagement with the frontline health workers [9], [11], [18]. Participatory and user-centered design methods have been also demonstrated to enhance usability, cultural relevance, and adoption in different populations [2], [7], [12], [14], [15]. Still, most of them are based on plain data capture forms and lack built-in clinical decision support, standardized maternal and perinatal death classification, and automatic alerting of high-risk cases [6], [17]. This means that their influence on early detection and timely intervention is limited.

Recent literature has investigated the use of clinical decision support and risk prediction models in the maternal health platform. These methods have been shown to have potential of the detection of high-risk pregnancies using physiological, demographic, and behavioral predictors, which can therefore be used to proactively intervene [6], [13], [18]. Although those have been done, there

are still numerous solutions that are research proposals with low scalability, lack of interoperability with other existing health information systems and role-based access control between the various groups of users [1], [19], [20]. Empirical assessments have also outlined some endemic difficulties in the area of care about data quality, dispersed reporting tools and parallel flow of information that hamper the full surveillance and reaction [4], [5], [16].

Within the framework of MPDSR, accountability, institutional learning, and the improvement of quality are best achieved through structured audit workflow. The current digital MPDSR platforms have tried to formalize audit procedures, which are often not integrated through to the reporting, review and response phases [4], [5], [8]. In addition, not many platforms offer the standardized support of maternal and perinatal death classification in agreement with international standards, which restricts the comparability and policy relevance of the gathered data in the regions and programs [16], [17]. Research in LMICs contexts still continues to record incomplete toolchains, absence of integration of the systems, and a poor connection between surveillance data and corrective action [6], [18], [19].

The paper fills these gaps by developing and deploying a Maternal Risk and Death Reporting System (MRDRS) incorporating real-time data capture, automatic risk notification, role-based access control, and formal audit reporting into a single system [1], [4], [17]. In comparison with the previous systems that are limited, and specific to reporting or prediction, the suggested solution puts emphasis on workflow integration, data integrity and deployment viability in a low-resource setting [21], [22], [23]. This work provides a viable and scalable technical basis to enhance maternal surveillance processes in the LMIC context through alignments between the system functionality and MPDSR operational requirements and usability evidence of the mHealth design research work [2], [7], [11], [18].

### Methodology and System Architecture

The given research selected the design-and-evaluate research methodology that is aimed at developing and testing a workable maternal risk and death reporting system in low-resource environments [6], [21], [24]. Implemented as a mobile-enabled application that is organized into modules, the system was developed to facilitate structured workflows of maternal and perinatal death surveillance and response (MPDSR) in line with evidence-based guidelines on digital health interventions in LMIC settings [4], [5], [18]. The process was iterative with the following lifecycle of requirements analysis, system design, implementation, functional testing and scenario-based testing, as per the conventional software development life cycle (SDLC) processes of health information systems [24], [25].

The general system layout was constructed in the form of a layered client server architecture comprising of presentation layer, an application services layer and data management layer [21], [22], [23]. The presentation layer will consist of role-specific user interfaces of different classes of users, such as community health workers, hospital administrators, and supervisory personnel, in line with usability and user-centered design principles in mHealth systems [2], [7], [9]. The business logic is located in the application services layer and performs user authentication, data validation, workflow orchestration, risk assessment and audit management [1], [19], [20]. Maternal risk indicators, case reports, audit records and user metadata are stored in a centralized relational database through the data management layer and access controls are implemented at application level in order to maintain the integrity and confidentiality of the data [19], [20]. This is displayed in Figure 1.

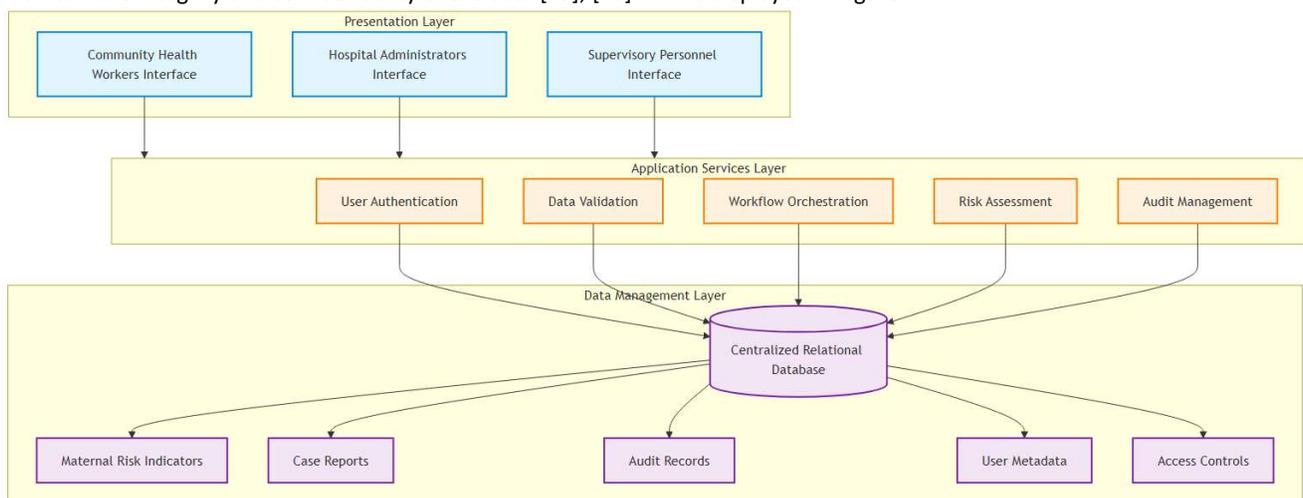


Figure 1. Layered Client–Server Architecture of the Maternal Risk and Death Reporting System (MRDRS)

The role-based access control (RBAC) was introduced to classify functional limits between the different types of users in line with security guidelines on e-health system [1], [20]. CHWs are empowered to enroll patients, file maternal risk factors and outcomes of pregnancy. Hospital administrators will have the responsibility of checking the reports, launching maternal and perinatal death audits, and organizing response measures. Aggregated reports, performance indicators and audit summaries are accessible to the supervisory users with read-only access. This separation of roles guarantees data integrity, accountability, and compliance with ethical and operational requirements that are found in the previous MPDSR and digital health researches [4], [6], [19].

The patient registration, maternal risk assessment, case reporting, audit management, alert generation, and reporting and analytics are the fundamental functional modules of the system [6], [17], [18]. The maternal risk evaluation module gathers structured physiological and demographic variables and uses predefined threshold guidelines to identify high-risk cases, which represent decision-support techniques in previous maternal health platforms [6], [13], [18]. The alert generation component is an automatic model that alerts the designated users when critical risk condition or death events are reported to aid in early intervention and the process of escalation [6], [9]. The audit management module facilitates formal records of the maternal and perinatal death review, which contains the classification of causes, contributing factors and recommended corrective action according to the operation guidelines of the MPDSR and the formalization of the audit process requirements [4], [5], [17].

Module	Function
Monitoring	Weekly clinical data capture
Risk Engine	Rule-based + ML risk evaluation
Alert System	High-risk notification
Audit Module	ICD-MM / ICD-PM reporting
Security Layer	RBAC and secure access

Table 1 Core Functional Modules of the MRDRS

A safe client-server architecture was incorporated to enable real-time information synchronization at mobile clients and the server computer [21], [22]. Any transactions are authenticated at the application layer to reject unfinished and/or inconsistent data submission to solve the recurrent data quality issues documented in LMIC health information systems [19], [20]. Encryption and authentication measures were also implemented to ensure confidentiality of patient data and guarantee controlled system access, which is in accordance with the security and privacy guidelines regarding digital health solutions [1], [20].

A modular web and mobile technology stack was used to launch the system that would enable cross-platform deployment and scalability [21], [22], [23]. The backend services were coded based on a RESTful application programming interface (API) so that they may be made interoperable with other health information systems, in line with the integration practice findings in previous mHealth and HIS literature [20], [21]. The data layer was executed in a form of a relational database schema optimized to transactional integrity and structured audit processes that facilitates efficient case tracking and review process [19], [20].

The evaluation of the system was performed using functional testing and simulation by scenarios [6], [24]. The user authentication, data capture, workflow transitions, alert triggering, and audit documentation were checked through functional testing, and they turned out to be correct. The behavior of the systems under simulation conditions based on the workflows of the representative maternal risks and mortality reporting processes, such as high-risk pregnancy detection, late case notification, and initiation of the audit, was evaluated with the help of scenario-based simulation [6], [18]. The metrics of evaluation were evaluations of data completeness, workflow consistency, and accuracy of alerts and role-based access controls, which represented the quality aspects that were found in earlier digital maternal health and MPDSR reviews [6], [19], [20].

## RESULTS AND DISCUSSIONS

Maternal Risk and Death Reporting System (MRDRS) that was implemented was tested using functional testing and scenario simulation to evaluate how it could support the structured maternal and perinatal death surveillance and response (MPDSR) processes [6], [24]. The findings suggest that this system has been effective in capturing maternal risks indicators, role-based access control, automatic alerts on high-risk cases and facilitating formal records on maternal and perinatal deaths audits. Such fundamental functions performed well in most representative workflow contexts, and prove that the proposed architecture is technically viable to be deployed in low-resource environments [4], [6], [18].

The validation of the proper functioning of the user authentication, patient registration, risk assessment and case reporting and audit initiation processes was carried out through functional testing. The role-based access control system was successful in

keeping the unauthorized actions at bay so as to classify cross-role manipulation of data and accountability of the workflow, as per the security best practices in e-health systems [1], [20]. The automated alert generation was activated consistently given any given risk threshold or death events recorded so that relevant users were promptly informed. These results are consistent with previous evidence that mobile-enabled reporting solutions have the potential to decrease the reporting lag and enhance early identification of high-risk pregnancies (in comparison with paper-based surveillance processes) [6], [9], [18].

Simulation Scenario-based simulation revealed that the system ensured data consistency and workflow continuity when subjected to representative conditions of maternal health reporting, such as late notification of cases and serial initiation of audit [6], [18]. The systematic audit management component assisted in standardized documentation of maternal and perinatal deaths review, classification of causes, contributing factors, as well as recommended corrective measures. This functionality is an important workaround to the weakness of many current digital maternal surveillance systems, which often do not support formal audit processes and end-to-end integration of MPDSR processes [4], [5], [8], [16].

The findings also reveal that the system has the potential to enhance accountability and coordination among community and facility-level actors. The system facilitates a centralized data capture and workflow orchestration (in real-time) that minimizes fragmentation of reporting, review, and response phases, which has always been highlighted in MPDSR implementation in LMIC settings [4], [5], [6]. The combination of automated warning and regular audits also increase the ability of the system to facilitate timely interventions and ongoing quality enhancement that portray operational needs that have been established in the earlier studies of maternal surveillance [6], [18], [19].

Although these are the strengths, various limitations have been determined. One, the assessment was performed in simulated conditions but not in real-world pilot deployment which restricted the generalizability of the results of observed performance outcomes [6], [18]. Secondly, the maternal risk assessment module is based on the predefined threshold rules instead of adaptive predictive models, which can limit the accuracy of the risk detection in heterogeneous clinical settings as previously demonstrated in decision-support and mHealth research [13], [18]. Third, the empirical validation of system scalability and national health information system interoperability were not conducted, even though their role in the sustainable implementation of MPDSR is highly accepted [19], [20]. These drawbacks indicate potential future improvements such as field test, incorporation of machine learning-based risk prediction and formal interoperability test.

In sum, the results of the evaluation show that the offered system offers a sustainable and effective technical base in enhancing the maternal risk and death reporting processes in low-resource settings [4], [6], [18]. The system bridging the main gaps in the operational workflows of current maternal surveillance procedures with respect to real-time data capture, automated notifications, role-oriented workflows, and structured audit records will help address the key gaps in the current practice of implementing the MPDSR on an international scale [5], [16], [19].

## Conclusion

This paper has developed and deployed a Maternal Risk and Death Reporting System (MRDRS) to facilitate formalized, mobile-enabled maternal and perinatal death surveillance and response (MPDSR) processes in low-resource areas [4], [6], [18]. The system combines real-time information capture, automated risk notifications, role-based access control, and organized audit records in a single platform and follows the operational and technical needs base found in the earlier researches of digital maternal health and MPDSR [1], [5], [17], [20]. Functional testing and scenario-based simulation proved that the system is able to record maternal risk factors, raise alerts in case of high-risk conditions, facilitate standard audit procedures, and impose access control limits on user groups [6], [24].

The results show that the suggested solution fills the critical areas of operation in the current maternal surveillance operations, such as late reporting, disjointed workflows, poor data-to-action connections, and insufficient accountability systems [4], [5], [6], [16]. The system enhances the coordination between community and facility level actors and early detection and timely intervention of high-risk pregnancies through a workflow-focused centralized system, which can meet the international priorities of implementing MPDSR [6], [18], [19]. The addition of automated notices and systematic audits increase the ability of the system to facilitate the continuous quality improvement and learning of the institution more in decentralized care setting [5], [16].

In spite of these inputs, the study has a number of limitations. To begin with, the experimentation was based on simulated testing scenarios, but not actual pilot deployment and, therefore, could not be generalized to actual performance results [6], [18]. Second, the maternal risk assessment module is currently using fixed threshold policy rather than adaptive predictive models, which can limit the accuracy of risk detection in diverse clinical settings, as has been observed in previous studies of decision-support [13], [18]. Third, there was no empirical validation of system scalability and other interoperability with national

health information systems, although this is identified as crucial to the sustainability of MPDSR implementation and health system integration [19], [20].

The future research should thus focus on field testing in representative health system environments, machine learning based risk prediction model integration, and formal interoperability testing with the national health information systems [13], [19], [20]. Further studies are also justified to determine long-term adoption by users, data quality results, and institutional effects of the platform in case of deploying it at scale [6], [18]. In general, the proposed system offers a viable and scalable technical framework to enhance maternal and perinatal death surveillance and response initiatives in low-resource settings, which offers a viable line of attack to more responsive, data-driven maternal health systems [4], [5], [16].



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