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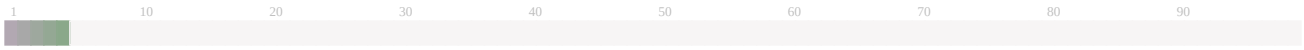

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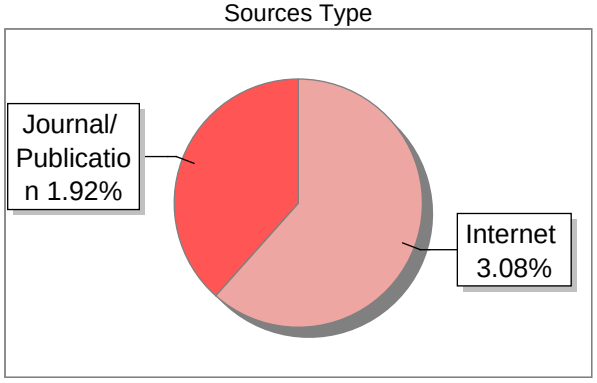

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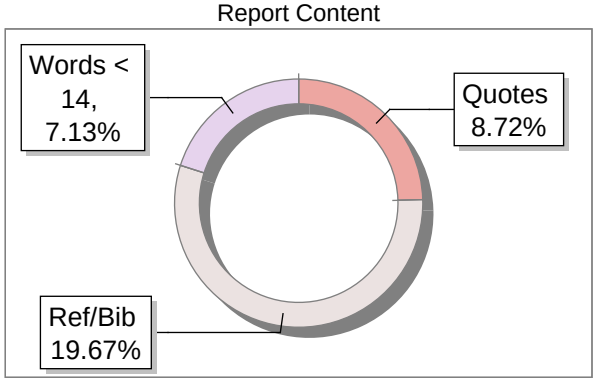

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ScreenMy: a Lightweight Architecture of Tuberculosis-Diabetes Mellitus Screening System Integrating with EMRs

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Abstract - Background: Early detection of diseases like tuberculosis (TB) and diabetes mellitus (DM) is critical for preventive healthcare. However, integrating effective screening programs within existing workflows can be challenging. Objective: This study explores the feasibility and impact of integrating an electronic screening system (ESS) within electronic medical records (EMRs) in private primary care settings. The pilot study focuses on ScreenMy, an ESS engine designed for bi-directional TB-DM screening. Methods: A pilot study investigated the integration process of ScreenMy into an EMR system. Interviews with developers assessed factors like installation ease, flexibility, and impact on the EMR's functionality. Findings: The findings revealed a smooth integration process due to ScreenMy's external design (requiring only plugin injection) and clear documentation. The integration maintained EMR performance and efficiency, enhanced the developer experience, and offered flexibility for customization. Developers, unfamiliar with prior integrated screening systems, found ScreenMy user-friendly and expressed interest in further system flexibility concerning data privacy. Conclusion: This investigation highlights the potential for seamless integration of screening systems like ScreenMy within EMRs. This paves the way for improved preventive healthcare delivery in primary care settings.

Keywords: Electronic Screening System (ESS) Integration, Electronic Medical Records (EMR) Integration Tuberculosis (TB) Screening, Diabetes Mellitus (DM) Screening, Preventive Healthcare, Primary Care Settings.

I. INTRODUCTION

Health screening plays a crucial role in secondary disease prevention by employing various tests to detect potential illnesses in their early stages, where intervention carries significantly greater efficacy. As a cornerstone of health promotion programs, this practice holds immense potential in mitigating morbidity and mortality rates across diverse populations [1]. By identifying health risks early, individuals can make lifestyle changes and seek appropriate medical care to reduce their risk of developing serious health problems. This can lead to improved overall health and well-being.

Timely identification plays a crucial role in enhancing patient outcomes, especially for those with pre-existing chronic illnesses like heart disease, cancer, and diabetes, where prompt intervention significantly improves prognosis [2]. In the case of diabetes, for example, the World Health Organization (WHO) has reported that 285 million people have diabetes, and 3.9 million deaths are linked to the condition. In January 2009, the WHO held a meeting to prioritize the review of research on the relationship between diabetes and tuberculosis (TB) infection. The meeting concluded that diabetes is associated with an increased risk of active TB, based on both case-control and cohort studies. Additionally, diabetes appears to have an impact on various TB treatment outcomes. Based on the evidence, the WHO developed a framework to guide the creation and implementation of efforts to decrease the burden of both diabetes and TB in populations affected by both diseases. These efforts involve collaboration between different organizations and stakeholders. [3]

According to the work of Barr and colleagues, an information system is a component of the expanded chronic care model (CCM). The CCM is a framework that aims to improve the management of chronic conditions, such as diabetes and TB, through a range of interventions including self-management support, delivery system design, decision support, and clinical information systems. These interventions work together to promote better outcomes for patients with chronic conditions. The use of information systems is key in supporting processes for change. In clinical

informatics, information systems can be used to advocate for new programs, assess existing ones, and support the adoption of new workflows. Information systems can be a useful tool in implementing and evaluating new initiatives in healthcare settings. [4]

Numerous studies have already been conducted in several countries, investigating the issue of bi-directional screening for tuberculosis (TB) in patients with diabetes mellitus (DM) [5], [6]. A study by Prakoso and colleagues indicated that implementing TB-DM screening in private clinics was well-received and feasible for screening diabetes patients for TB concurrently [7]. These studies primarily examine the challenges associated with screening DM patients for TB within healthcare facilities. One of them clearly proposes the utilization of Electronic Medical Records (EMR) as a means to enhance the performance of screening processes [5]. Study by Hashal [8] closely examines the operational layer of TB-DM screening. However, it is important to highlight that this particular study does not incorporate the utilization of information technology as a means to address data integration concerns. Consequently, there remains a significant gap in the literature regarding the incorporation of information technology into the operational aspects of TB-DM screening programs.

While Rahayu et al. [9] presented a standalone mobile app for TB screening, other research suggests advantages to integrating such tools with electronic medical records (EMR). For example, a study by Steinberg et al. [10] demonstrated the feasibility of implementing a universal screening tool within an EHR, and other research [11] indicates potential benefits for broader health screening through EMR-based approaches. This suggests that future efforts in developing screening systems might prioritize seamless integration with existing EMR infrastructure for wider impact.

The research conducted by Rahayu [9] is a recent study on the development of a health screening system to enhance the implementation of bidirectional screening for TB-DM. Previous research [11] has been conducted on health screening, but none specifically focused on TB-DM screening. Therefore, this research represents an important contribution in expanding our understanding and knowledge of TB-DM screening.

Electronic Medical Record (EMR) is the real implementation of Information System in healthcare settings. EMRs are digital versions of a patient's medical records that can be accessed and updated electronically. The use of EMR can help healthcare workers (HCWs) in their daily tasks [13]. EMR or health information system (HIS) technology utilization showed potential benefits in improving disease control and surveillance, care management, and patient outcomes [14], [15], [16]. The previous study found that Well-designed interventions and technology support effectively improved screening and data collection [17]. The data gathered from EMR can be used to convince decision-makers and stakeholders to invest in these programs [4]. However, the study of integrating screening systems inside EMR has not yet been conducted.

This study focuses on the utilization of Information System (IS) to improve the health screening process in primary care, with an emphasis on developing a lightweight architecture for an electronic screening system (ESS) that can be efficiently integrated with electronic medical records (EMRs). Although digitalization in health screening holds potential for various types of screening, this study specifically targets TB-DM screening. The objective of this research is to explore the feasibility and impact of integrating the ScreenMy ESS engine within EMRs in private primary care settings, aiming to enhance the efficiency and flexibility of TB-DM screening processes. This new research contributes by proposing an innovative, lightweight ESS architecture designed for seamless integration with EMRs, maintaining system performance and offering customization flexibility, thereby paving the way for improved preventive healthcare delivery.

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Reviewer comment: "Please provide contributions and new research in the Introduction section"

II. METHOD

This study follows three main steps including the need for analysis of ESS, ESS development, and pilot study of ESS in real world implementation.

Fig. 1 The main research steps

A. Requirement Analysis

The objective of this step is to define the functional requirements of ESS based on the perspectives and experiences of private healthcare workers (HCWs) in the implementation of health screening. In this case, the study focused on bi-directional screening for TB and diabetes. The study used interviews and focus groups discussions (FGDs), to gather in-depth information about HCWs' views and experiences with this screening process. In order to gather information about the technical aspects of ESS implementation, the research also involved conducting interviews with information system technicians at primary care providers (PPCs). These interviews were designed to gather information about the technical requirements, resources, and challenges associated with integrating an ESS into existing EMR systems and existing web-based health information systems (HIS) used by PPCs.

B. System Development

Based on the information gathered in the assessment phase, the research team would design and develop the electronic screening services (ESS) system. The development phase is using Feature Driven Development (FDD). Feature Driven Development (FDD) is an agile software development process that emphasizes delivering functional features to the users in a timely manner. It is an adaptive approach that is flexible and easy to adapt to changing requirements. It utilizes a five-step process that includes planning, developing by feature, designing by feature, constructing by feature, and deploying [18].

C. Pilot Study Procedures

The pilot study procedures used in this study follows and adopts the general research process for case studies proposed by Runeson et al1 [19], which consists of the following basic steps: design, planning, data collection, data analysis, and reporting. The pilot study adopts a single-case, holistic design, concentrating on the specific instance of pilot study. The main area of investigation within this pilot study is the ScreenMy engine, as resulted in the previous step. The primary research question guiding this pilot study is: "What technical challenges and opportunities emerge in the integration of a ScreenMy engine into the Electronic Medical Record (EMR) system within a private primary care (PPC) facility?" Table 6 outlines the Main Research Question (MRQ) and Secondary Research Questions (SRQ) that structure the inquiry.

TABLE I
RESEARCH QUESTION OF THE PILOT STUDY

Research Question	Description
MRQ	What technical challenges and opportunities emerge in the integration of a ScreenMy engine into the Electronic Medical Record (EMR) system within a private primary care (PPC) facility?
SRQ 1	What specific technical challenges arise during the integration process of the screening engine into the Electronic Medical Record (EMR) system at the private primary care facility?
SRQ 2	What is the impact of these challenges impacting the overall functionality of the EMR system?

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Reviewer comment: It is better to replace the term "need analysis" with "requirement analysis"

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The pilot study took place within a genuine organizational setting, implementing ScreenMy engine into the Electronic Medical Record (EMR) system. The incorporation of the ScreenMy engine into the EMR system involved the expertise of a developer from the information system division. The integration process follows a structured sequence: 1) Initiation of a meeting with the developer to discuss the technical requirements and integration procedures. 2) Provision of documentation resources to aid the developer. 3) Subsequent meetings with the developer to assess and discuss the outcomes of the integration process.

III. RESULT AND DISCUSSION

A. The Requirement Analysis of ESS

The first step of the study was an assessment, which included focus group discussions (FGDs) with 15 healthcare workers (HCWs) from 5 private primary care practices (PPCs). The participants in the FGDs had an age range of 28-44 years and an average age of 32.5 years. The majority of the participants were women (80.1%), and they had an average length of employment of 7.2 years, ranging from 1.5 to 16 years. The participants came from a variety of healthcare backgrounds, including medical doctors, nurses, and midwives. Based on the reports from the participants in the FGDs, the study identified the urgency of an integrated information system for screening, specifically the integration with an existing electronic medical record (EMR).

In the development phase of the ESS, the researchers needed more detailed information about the functional and nonfunctional requirements of the screening system. To gather this information, we conducted discussions with management, doctors, and information system technicians at one of the private primary care practices (PPCs). The functional requirements relate to how healthcare workers (HCWs) and management use the system, while the nonfunctional requirements concern how the system is deployed. These discussions provided valuable insights that helped inform the design and development of the ESS.

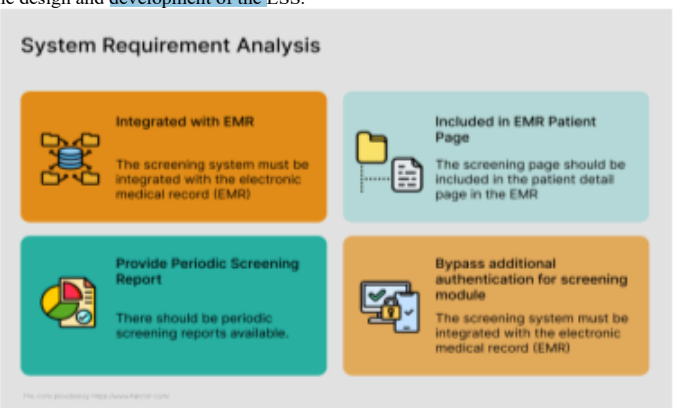

Fig. 2 Requirements identified based on FGD

Based on the reports from the participants in the discussion, the study identified four main requirements for the electronic screening system (ESS) as shown in Fig. 2. The details of these requirements are as follows: 1) The screening system must be integrated with the electronic medical record (EMR) through a secure application programming interface (API), 2) The screening page should be included in the patient detail page in the EMR, 3) There should be periodic screening reports available, and 4) Healthcare workers (HCWs) should not need to do additional user authentication in order to perform the screening.

B. System Architecture and Design

The Electronic Screening Services (ESS) comprises four integral components that collectively contribute to its seamless and effective functioning (see Figure 3). At the core of this system lies the ScreenMy engine, serving as the primary driving force behind the screening mechanism. Accompanying the ScreenMy engine is the dashboard app, a user-friendly interface designed to facilitate screening configuration and generate comprehensive reports. This component empowers healthcare professionals with the necessary tools to customize screening parameters and gain valuable insights from the collected data. Another crucial element is the screening form display, dedicated to the meticulous collection of screening data. This feature ensures that the information gathered is accurate, comprehensive, and easily accessible for analysis. Lastly, the ScreenMy Javascript library plays a pivotal role by being embedded within the Electronic Medical Records (ERM) system. This library acts as a communication bridge between ESS and ERM, fostering seamless integration and data exchange. Together, these four components form a cohesive and efficient Electronic Screening Services system that enhances the screening process while providing valuable tools for configuration, reporting, data collection, and integration with Electronic Medical Records.

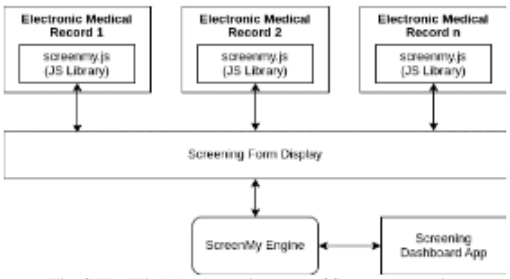

Fig. 3 The High-level architecture of ScreenMy engine

Basically, ESS and EMR are two separate systems that can run independently (see Fig. 4). ScreenMy has an independent server and database that communicates with EMR using ScreenMy javascript in the library (Fig. 4.10). This pattern allows the system to integrate data within and between EMR, and also not interfere too much with EMR except installing ScreenMy library inside EMR.

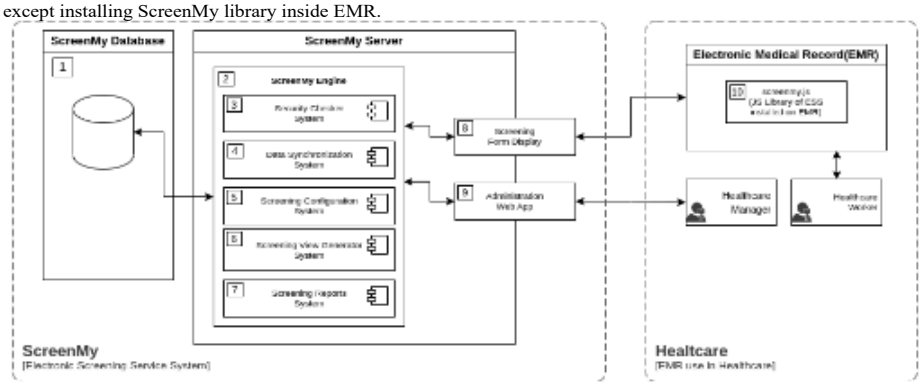

Fig. 4 The architecture of ScreenMy and its relationship with EMR

The ScreenMy library is intended to make ESS easier for an EMR developer to install the screening system without the need for extensive configuration. According to the discussion, the developer reported that it would be difficult to develop the screening system directly within the EMR. Instead, the library allows for the integration of the ESS system with the EMR in a more streamlined and flexible manner. The library used in this study allows the EMR to display the screening page (Fig. 4.8) without the need for opening a new page or application in the browser by utilizing the popup window of the browser. This means that healthcare workers (HCWs) do not need to leave the EMR to perform the screening. Instead, the screening page is loaded from the screening view generator system (SVGS) (Fig. 4.6) and displayed within the EMR using a popup window. This can help to improve the efficiency and convenience of the screening process, as HCWs can access the necessary tools and information without having to switch between different applications.

C. Interaction Design

The user interaction design is based on the perspective of a health worker collecting data during the requirement analysis phase. The design, as shown in Fig. 5, depicts a workflow where the doctor focuses solely on health screening activities and does not input any patient data. In practice, nurses typically collect basic patient data such as weight and blood pressure. To accommodate this workflow, ScreenMy offers the option to conduct a screening immediately or at a later time.

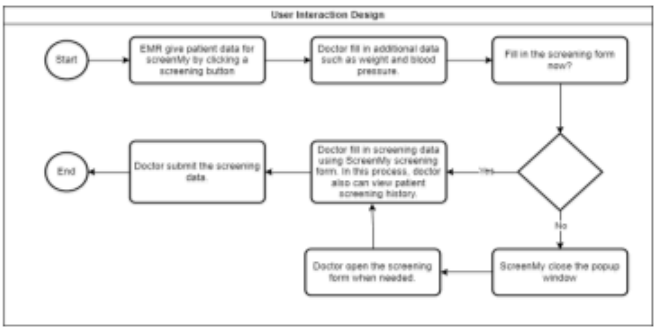

Fig. 5 User interaction design of ScreenMy

D. Integration

This study investigated integrating an electronic screening system (ESS) with electronic medical records (EMR) to improve screening efficiency, focusing on ScreenMy, a system designed for TB-DM bi-directional screening. Findings showed a smooth integration process, with ScreenMy accessing patient data from the EMR via the National Identity Card number (NIK) stored in a library. This data exchange improves screening efficiency by providing up-to-date and accurate information. Additionally, the study emphasizes the importance of integrating screening procedures through information technology, particularly the ESS system's ability to share screening data between primary care providers (PPCs) leveraging a Data Synchronize System (DSS) component (as illustrated in Fig. 4.4). This data exchange, facilitated by the ESS framework, ensures continuity and coherence of patient care across different healthcare facilities.

E. Customization and Report System

The Electronic Screening Service (ESS) system goes beyond data exchange by incorporating a Screening Configuration System (SCS) (Fig. 4.5) to manage and customize screening programs for specific patient populations. This allows healthcare providers to adapt and optimize screening procedures for better accuracy. Additionally, the ESS system includes a Reporting System (RS) (Fig. 4.7) that generates two types of reports: screening history reports for doctors to view past patient data and time-based reports for analyzing trends. These reports provide valuable

insights to improve patient care by offering a more complete picture of a patient's health history. This model aligns with existing studies recognizing the potential of clinical decision support (CDS) tools within EMR systems to enhance patient care and streamline clinician workflows [20].

F. Security

The library used in this study includes a security token system to meet the security requirements of the system, as reported in the discussion. Private primary care practices (PPCs) must be registered with the electronic screening services (ESS) in order to obtain a security token. The ESS then uses a security checking system (SCS) (Fig. 4.3) to confirm and verify the transaction of data using the security token. This procedure allows healthcare workers (HCWs) to perform the screening without the need for additional authentication beyond the authentication required to access the electronic medical record (EMR). The use of security tokens helps to protect against unauthorized access to the screening system and ensures that only authorized users are able to perform screenings.

The current security token system employed in this study provides a solid foundation for secure data access, but future iterations could benefit from exploring more advanced decentralized technologies. Research [21] indicates promise in leveraging decentralized solutions like blockchain for secure data storage and access control. Furthermore, the proposed solution in previous research [21], which utilized deep learning and decentralized technologies for personal medical device security, offers intriguing possibilities for the ESS. Integrating similar concepts into the ESS framework could create an even more robust and secure environment for screening data and protect it from emerging cyber threats.

G. Analysis of Results from The Pilot Study

The pilot study investigated the integration of the ScreenMy system into an electronic medical record (EMR) system and its subsequent impact on EMR functionality. Developers reported a seamless integration process, facilitated by ScreenMy's external nature, which required only the injection of plugins and buttons without extensive modifications to the EMR core system. Satisfaction with the provided documentation was rated highly, reflecting clear and comprehensive installation instructions. The integration was found to positively influence EMR performance and efficiency, with developers rating their satisfaction with these aspects at 5/5. Furthermore, the system's flexibility and customization capabilities were also rated highly, indicating its adaptability to specific EMR needs. Interestingly, developers had no prior experience with integrated EMR screening systems, suggesting that ScreenMy could be particularly accessible to new users. There were no immediate requests for additional features, highlighting ScreenMy's sufficiency for basic health screening functions. However, developers suggested the future option of using their own domain for integration to enhance system flexibility and privacy, as current testing utilized a subdomain.

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H. Discussion

This research explores the most efficient architecture for integrating a specific type of electronic screening system (ESS) with electronic medical records (EMR), specifically from the perspective of EMR developers. Through interviews with developers, the study investigated four key aspects: ease of installation, flexibility, user satisfaction, and the perceived impact on existing EMRs. The findings suggest that building an external ESS presents several advantages for EMR developers, particularly in terms of simplified integration.

The previous research on the use of electronic medical records (EMR) in Indonesia has primarily focused on how these systems can be used to record patient data, facilitate data exchange between healthcare providers, and track patient data over time [22], [23]. While there have been several studies [9], [6] on health screening, many of these do not integrate with EMR systems. According to our study, the doctors have difficulties in implementing the screening process if it is separated from the EMR. This suggests that integrating the screening process within the EMR would make it more convenient and user-friendly for doctors to perform the screening, resulting in a more efficient and effective process overall.

The improvements made in this study involve creating an external nature of the EMR but implementable in EMR. The previous study [24] also used the same approach to create a decision support system for public health decision making. A modular approach has also been carried out by other research [25] to create an emergency EMR system to counter the COVID-19 disaster, which utilizes the modular architectural concept in openEMR (https://openmrs.org/) [26]. This work gives a solution for the lack of integrated strategy for data collection and analysis, which hinders effective management of TB and DM at the primary healthcare level [27].

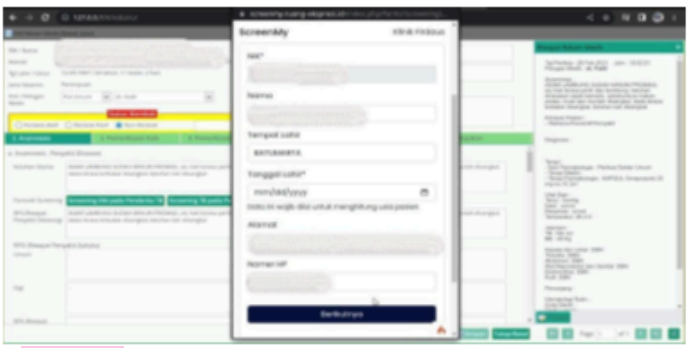

Fig. 6 The result of the ScreenMy implementation inside EMR used by PPC in the case study

As a proof of concept for the screening system, this study implemented bi-directional screening for TB-DM by installing TB screening and DM screening buttons as seen in Fig. 6. This study addresses the challenge of ensuring private practitioner compliance with mandatory tuberculosis case notification, as highlighted in prior research [28]. The Electronic Screening System (ESS) introduces a novel contribution by providing centralized TB-DM screening data and facilitating its seamless integration into web-based electronic medical records (EMRs) through a modular approach. As has been done in previous research, the centralized approach aims to improve adherence to screening protocols by ensuring that screening processes are streamlined and consistently applied across all participants [29]. This modular design streamlines the submission of TB case notifications for private practitioners, leading to efficient resource utilization within the screening process. However, next research can adopt the blockchain architecture [30] to improve the integrity and security of healthcare data. When a large amount of data has been gathered, the system can utilize intelligent identification methods, like the Minkowski distance similarity method in Case-based Reasoning (CBR) [31], to automatically diagnose diseases.

IV. CONCLUSION

This study provides significant insights into the integration of an electronic screening system (ESS) within electronic medical record (EMR) systems, highlighting the technical challenges, opportunities, and overall impact on EMR functionality in private primary care (PPC) settings. The findings reveal that integrating the ScreenMy ESS engine into EMRs presents minimal technical challenges and offers several opportunities (MRQ). The pilot implementation demonstrated that developers could integrate ScreenMy by simply injecting plugins and buttons without extensive modifications to the core system, streamlining the integration process (MRQ). Specific technical challenges were minimal, with developers reporting no significant issues due to ScreenMy's external nature and comprehensive documentation, resulting in high satisfaction ratings (SRQ 1). The impact on overall EMR functionality was positive, maintaining performance and efficiency, and the system's flexibility and customization capabilities were highly rated (SRQ 2). Additional findings included the potential for ScreenMy's adoption among new users and a recommendation for using a dedicated domain for future integrations to enhance flexibility and privacy. Overall, a modular ESS like ScreenMy can help PPCs improve healthcare services while saving resources. Future work will focus on refining the integration process, enhancing customization, and exploring broader applications across different healthcare settings, including adopting blockchain architecture to enhance data integrity and security.

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Reviewer comment: The Conclusion section should briefly answer the three existing research questions

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