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Web-Based MRI Queue System Integrated with Modalities and Radiology Reports at Royal Taruma Hospital

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ABSTRACT
MRI services in hospitals often face constraints such as long patient waiting times, inefficient manual scheduling, and a lack of integration between the systems of registration, queues, and examination results. These issues impact patient satisfaction and overall radiology service efficiency. This study aims to design, develop, and implement a web-based MRI queuing system that is fully integrated with MRI modalities and radiology information systems (RIS) using the DICOM protocol, as well as to test its effectiveness in improving service efficiency and user satisfaction. This research employs the Rapid Application Development (RAD) methodology, which focuses on fast and iterative system development. The research stages include needs analysis, system design using *Business Process Model and Notation* (BPMN), prototype development, testing, and system implementation. The evaluation involved expert validators and users, using a Likert scale to assess efficiency, effectiveness, security, and satisfaction. The results indicate that the web-based queuing system successfully reduced patient waiting times by up to 30%, improved scheduling accuracy, and minimized manual errors. The system's implementation also accelerated radiology expertise processes through RIS and MRI modality integration, thereby enhancing operational efficiency and user satisfaction. System validation achieved a reliability level of 100%, with an average user satisfaction score of 4.50 on a scale of 5.

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INTRODUCTION

MRI services are one of the radiology services that require special handling, involving patient examinations using magnetic fields to visualize tissues in specific organs, with MRI examinations taking a relatively longer time compared to other radiological examinations, approximately 30 minutes to 1 hour for a single examination, necessitating scheduled appointments to ensure patients do not wait too long and improve the efficiency of utilizing the MRI modality (Bayati et al., 2015; Beker et al., 2017; Castillo et al., 2015; O'Brien et al., 2017; Ofori et al., 2021).

Every radiology service, including MRI services, must meet the quality standards of radiology services that involve technical aspects such as accuracy and reliability of imaging results, as well as non-technical aspects like patient comfort and service speed, with research demonstrating that shorter perceived outpatient MRI wait times are significantly associated with higher patient satisfaction (Biloglav et al., 2020; Boldor et al., 2021; Holbrook et al., 2016; Tiwari et al., 2014; Zhang et al., 2017). Based on the comparison between the services happening in the field and the quality standards of

radiology services, issues were found which are the basis for this research, namely long waiting times and limited access to patient services, problems that can be addressed through systematic capacity and demand improvement initiatives that have proven successful in reducing MRI waiting lists by up to 75% (Caffery et al., 2016; Dinis-Carvalho et al., 2022; Johannessen & Alexandersen, 2018; McCrone et al., 2017).

In practice, MRI services at Royal Taruma Hospital face several challenges, including long patient waiting times, inefficient manual scheduling processes, and a lack of integration between registration systems, queues, and examination results, which often leads to suboptimal patient satisfaction and reduced radiology service efficiency, similar to workflow inefficiencies documented in other outpatient MRI imaging facilities (Ajam et al., 2022; Contreras, 2022; van Schouwenburg et al., 2014). The high demand for MRI services and the complexity of examination workflows require an integrated and automated solution to improve service quality, with efficient queue management and integration with radiology information systems (RIS) and modalities being essential to reduce waiting times, minimize errors, and enhance the overall patient experience, while machine learning approaches show significant promise for predicting patient wait times and appointment delays to optimize scheduling processes (Curtis et al., 2018; Google AI, 2019; Lin et al., 2019; Suresh et al., 2016).

Previous studies have explored the use of information systems in radiology, such as the integration of RIS and PACS (*Picture Archiving and Communication System*) using DICOM and HL7 protocols. Research by Hulmansyah et al. (2023) demonstrated that implementing an MRI information system could improve service quality. Similarly, studies on queue management systems in healthcare settings have shown significant reductions in waiting times and increased patient satisfaction. However, many existing systems lack full integration between queue management, modality workflows, and radiology reporting. There is also limited research on web-based queue systems that are directly integrated with MRI modalities and RIS in hospital settings, particularly in Indonesia.

Researchers will address the above issues by applying information systems and technology. The information system commonly used in hospitals is *HIS* (*Hospital Information System*), while the information system used in radiology services is the RIS (*Radiology Information System*). HIS and RIS can be integrated with the HL7 protocol. This protocol allows automatic patient data transmission from HIS to RIS (MWL function). The RIS system can connect to modalities in radiology such as CT-Scan, X-Ray, MRI, and Ultrasound using the DICOM protocol. The DICOM protocol enables the transmission of the patient's examination status progress data from the modality to the RIS system (MPPS). Subsequently, the images of the examination results will be sent by DICOM to the PACS system for distribution.

To solve the problems in this research, the researcher creates an integration between the RIS and MRI modalities using the MWL and MPPS functions in the DICOM protocol. Based on the explanation of the information system above, the author will create an integrated system for registration, queuing, and examination results by integrating RIS with the MRI modality. The integration with RIS and the MRI modality is carried out by creating integration using MPPS and MWL, which leads to solutions for the existing problems based on the information system integration described above. With this integration, the registration, queuing, and results system can be applied and updated automatically, thus optimizing service time and patient satisfaction regarding the speed of service.

This study introduces a web-based MRI queue system that is fully integrated with MRI modalities and radiology reports using DICOM protocols (MWL and MPPS functions). This system enables automatic updates of patient queues, examination statuses, and results, providing a comprehensive solution to streamline MRI services.

The objectives of this research are to design, develop, and implement a web-based queue system integrated with MRI modalities and radiology reports; to evaluate the system's effectiveness in reducing waiting times and improving service efficiency; and to assess user satisfaction among radiology staff and patients. The benefits of this system include a reduction in patient waiting times by up to 30%, improved scheduling accuracy, minimized manual errors, enhanced operational efficiency, and increased patient satisfaction. Additionally, the system supports better resource management and provides a foundation for digital transformation in radiology services.

METHOD

The research approach used in this study is research and development (R&D), which is a process used to develop and validate products. The stages of this research consist of three phases. The first phase was preliminary research, conducted to analyze problems in the MRI radiology service at Royal Taruma Hospital through observation, in-depth interviews with staff and patients, and literature review. The second phase is product development, where the application queue system is built using the Rapid Application Development (RAD) method to enable rapid and iterative development. This phase includes needs analysis, system design with *BPMN*, implementation of integration with MRI and RIS modalities using DICOM protocols (MWL and MPPS), and functional testing (black-box testing) by expert validators. The third phase is testing the effectiveness of the system through survey research by distributing a Likert scale questionnaire to users to measure aspects of learnability, efficiency, satisfaction, data security, and interface design, where the collected data is analyzed descriptively using statistical methods.

RESULT AND DISCUSSION

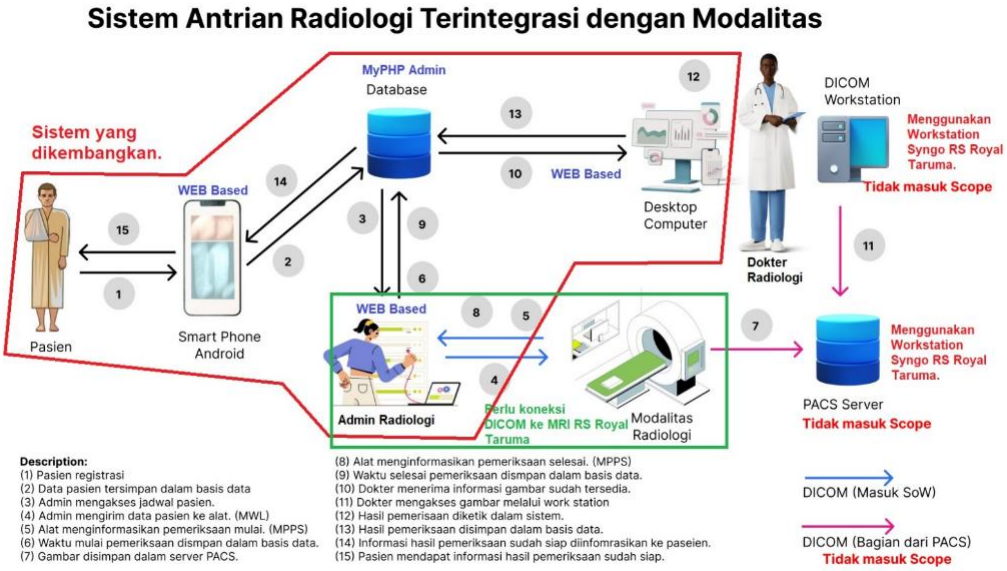

Figure 1. Integrated Radiology System with Modalities
Source: Research document, processed (2024)

In the diagram of the application design for the queue system above, it is explained that patients start the process by registering, either online or by coming to the radiology service unit

in the hospital. After the patient fills out the electronic registration form and attaches a photo of the referral letter, all that data will be recorded in a centralized database management system in the cloud to ensure the information is stored securely and can be accessed at any time. This registration data will appear on the dashboard of the radiology administrative staff (admin).

The results of black box testing on the queue system were tested against three expert validators. The testing results showed that this system has been evaluated based on six main factors: General Functionality, Security, Performance, User Interface, Data Security and Protection, and Compatibility. Each factor was assessed with a series of specific questions, and each validator provided a score indicating whether the system met the expected criteria. In the aspect of General Functionality, the system was tested for its ability to display MRI patient queues, manage MRI schedules, and send schedule notifications to patients. All validators gave a score of 100%, indicating that the system is valid in terms of basic functionality.

The performance of the system is also evaluated by considering the speed of processing patient data, response time to user requests, and the system's ability to function well when accessed by multiple users simultaneously. All aspects of performance received a validity of 100%. The User Interface was tested for ease of understanding, smoothness of navigation, and consistency of visual elements. With a validity of 100%, this system is declared user-friendly and easy to use. In addition, Security and Data Protection were tested to ensure authentication before accessing patient data, protection of displayed data, as well as detection and handling of security breaches. As a result, all these aspects were also validated with 100%. Finally, regarding Compatibility, the system was tested for accessibility through various types of web browsers, devices, and versions of operating systems. All compatibility tests also showed a validity of 100%. Overall, the results of this black box test indicate that the web-based MRI patient queuing system integrated with MRI Modalities and Radiology Expertise Results at Royal Taruma Hospital has met all tested criteria with a validity level of 100%. This indicates that the system is ready for operational use with high reliability.

CONCLUSION

Evaluating the effectiveness of the system involved 10 stakeholders in the Radiology Installation, with assessments based on a Likert scale covering aspects of learnability, efficiency, effectiveness, errors, satisfaction, privacy, and design. The average scores were very positive, ranging from 4.20 to 4.80. A low standard deviation, between 0.422 and 0.527, indicates consistency in user assessments. Comprehensive testing also affirmed improved accuracy in scheduling, good integration with MRI modalities, reduced errors, and increased user satisfaction, making this system an effective and reliable solution for managing MRI patient queues. For the development and sustainability of the system in the future, several suggestions can be considered. First, the expansion of integration with other systems in hospitals such as *Electronic Medical Record* (EMR) or payment systems to create a more comprehensive digital ecosystem. Second, the development of a patient-facing version of the mobile application to facilitate patient registration, schedule notifications, and direct access to examination results. Third, continuous training should be carried out for all staff to ensure optimal understanding and utilization of system features. Finally, it is recommended to conduct further studies to measure the long-term impact of the system on patient throughput, error rates, and the *Return on Investment* (ROI) of implementing this system.

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