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Development of an Orthanc Pacs-Based Radiology Information System (RIS) at The Ilyas Tarakan Type D Navy Hospital

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ABSTRACT

Digital transformation in radiology management is urgently needed to improve accuracy, efficiency, and compliance with medical data retention standards. However, many type C and D hospitals in Indonesia still rely on paper- and film-based workflows because commercial Picture Archiving and Communication System (PACS) solutions are costly. This research aimed to design, develop, and evaluate an integrated Radiology Information System (RIS) based on the open-source Orthanc PACS at Ilyas Tarakan Naval Hospital, a type D hospital, to address radiology data fragmentation, limited Digital Imaging and Communications in Medicine (DICOM) storage on modality consoles, and paper-based reporting workflows. A Research and Development (R&D) approach was employed using the Rapid Application Development (RAD) model, consisting of a preliminary study, system development, expert validation through black-box testing, and limited pilot testing using a pre-test/post-test design involving ten respondents. The RIS was developed using Laravel and Bootstrap and integrated with Orthanc PACS through a Modality Worklist (MWL) mechanism. System performance was analyzed using normality, homogeneity, and Mann–Whitney statistical tests. Expert validation showed 100% validity across functionality, performance, user interface, security, compatibility, error handling, and usability aspects, while the integration aspect could not be evaluated due to hospital policy constraints. Pilot testing demonstrated a significant improvement in usability across all seven measured dimensions, with a Mann–Whitney test result of $p = 0.000$ ($p < 0.05$). The Orthanc-based RIS-PACS provided an effective and low-cost model for digitizing radiology services in budget-constrained type D hospitals and is recommended for gradual integration with the hospital information system.

INTRODUCTION

Digital transformation in the health sector has become an urgent necessity, particularly in radiology data management. It involves the use of information and communication technology to support various aspects of healthcare services, including medical data management, and has been shown to reduce errors, increase efficiency, and improve healthcare outcomes (Thimbleby, 2019). The implementation of a Picture Archiving and Communication System (PACS) has further demonstrated benefits in improving data security, reducing human error, facilitating the storage, access, and processing of medical data, and enabling integration among hospital departments, thereby accelerating diagnosis and patient care (Reiner & Siegel & Carrino J. A., 2002)

Despite these benefits, many type C and D hospitals in Indonesia still rely on paper- and film-based systems for radiology services, largely due to the high implementation costs of commercial PACS solutions (Montazeri & Khajouei R., 2022). Film-based systems require X-ray films to be chemically processed before image interpretation; although this approach has been used for decades, it requires substantial physical storage space and limits rapid image retrieval (Montazeri & Khajouei R., 2022). PACS was developed to manage, store, and distribute medical images digitally, enabling rapid access without physical storage requirements and reducing turnaround times for radiology services (Setyawan, 2024). However, the costs associated with PACS implementation, including hardware, software, and staff training, remain major barriers for budget-constrained hospitals, particularly type C and D facilities (Abbasi Sadeqi Jabali M. & Khajouei & Tadayon H., 2020). Technical challenges, including system downtime during peak service periods, also discourage hospitals from transitioning away from film-based workflows (Floyd et al., 2015)

At Ilyas Tarakan Naval Hospital, radiology data management still relies on a paper-based system with several limitations, including risks of data loss and restricted storage capacity. A data loss incident involving Digital Imaging and Communications in Medicine (DICOM) files occurred on the hospital's X-ray console, which relied on a single storage console that frequently reached capacity due to the high volume of radiology examinations without adequate storage provisioning. This limitation prevented DICOM data from being retained for more than five years, which was inconsistent with the Regulation of the Minister of Health of the Republic of Indonesia Number 269 of 2008 on Medical Records, requiring medical records to be stored for a minimum of five years. Failure to comply with this requirement may compromise healthcare service quality, while type D hospitals with limited financial resources face significant challenges in adopting expensive commercial PACS solutions. Previous PACS implementations have demonstrated improvements in patient waiting times, diagnostic accuracy, and reductions in operational costs associated with paper-based radiology film workflows (Meyer et al., 2014).

This study focused on developing a paperless expertise-reporting system integrated with PACS while maintaining DICOM data quality. Currently, Ilyas Tarakan Naval Hospital relies on radiology image consultations through Telegram between radiographers and specialist radiologists, where images are shared in Joint Photographic Experts Group (JPEG) format rather than the original DICOM format. Therefore, this study developed a Radiology Information System (RIS) based on Orthanc PACS, enabling physicians to access DICOM images and prepare expertise reports digitally through an integrated platform. An affordable and efficient solution was required, and this study focused on developing an expertise-reporting information system using Orthanc, an open-source platform for DICOM data management that can be implemented at substantially lower costs than commercial PACS solutions (Jodogne, 2018). Open-source PACS platforms such as Orthanc enable secure DICOM storage and distribution while improving integration between radiographers and specialist physicians. These platforms also provide a more cost-efficient alternative to commercial solutions without compromising image or data quality (Garrevoet & Smith & Vandewalle P., 2021). Beyond reducing implementation costs, open-source PACS solutions provide greater flexibility for adaptation to different hospital infrastructures and integration with existing information systems.

Beyond data-management efficiency, the transition from film-based to digital radiology has significant implications for hospital operational and revenue management. Film-based radiology requires recurring costs for film, developing chemicals, and printer maintenance, while manual processes may prolong patient waiting times and reduce service throughput. Digital transformation has been shown to improve healthcare quality, reduce medical errors, and increase operational efficiency (Buntin et al., 2011). Digitizing radiology management through PACS not only improves clinical efficiency but also reduces long-term operational costs related to physical film storage and chemical processing. Furthermore, it increases radiology service capacity, accelerates reporting processes, and facilitates collaboration among healthcare professionals, particularly in complex cases requiring second opinions (Himuro & Nakagawa & Ito Y., 2022). Digital radiology systems also reduce diagnostic errors caused by degraded film quality, enable more accurate image evaluation, and support efficient comparison with patients' previous imaging records, thereby improving diagnostic accuracy (Becker & Green & Liu Y., 2023).

This study aimed not only to develop an improved information system but also to demonstrate how open-source technology, such as Orthanc, could improve efficiency and service quality in healthcare settings. The developed system is expected to serve as a reference for other type D hospitals seeking to adopt digital radiology data management while reducing operational costs and improving service throughput.

Based on the background above, the research problems addressed in this study were formulated as follows: (1) how could a Radiology Information System (RIS) based on Orthanc PACS be designed and developed at Ilyas Tarakan Naval Hospital, a type D hospital; (2) how did the developed RIS based on Orthanc PACS function; (3) how did the system perform under functional testing; and (4) how effective was the developed product model. This study aimed to: (1) develop a Radiology Information System (RIS) based on Orthanc PACS at Ilyas Tarakan Naval Hospital; (2) describe the operational processes of the developed system; (3) evaluate system functionality through expert validation; and (4) determine system effectiveness through pre-test and post-test evaluations. Theoretically, this study contributes to the development of health information system research, particularly regarding the implementation of open-source PACS solutions such as Orthanc, and provides a reference for future studies on healthcare information technology development. Practically, the resulting system is expected to assist radiographers and radiologists at Ilyas Tarakan Naval Hospital in managing radiology data more efficiently, support hospital management in improving service quality, and provide researchers with practical experience in developing applied healthcare information systems.

METHOD

This study used a Research and Development (R&D) design to develop and validate the proposed product. The development process began with a review of previous findings relevant to the product, followed by product construction, field testing in the intended implementation environment, evaluation of identified limitations, and subsequent refinement to improve quality and performance (Heeks, 2006) The development approach applied was Rapid Application Development (RAD), introduced by James Martin, which was selected because it supports structured stages and iterative development cycles that enable efficient software refinement based on evaluation results (Martin, 1991)

Table 1. Stages of the Rapid Application Development (RAD) Model

Stage	Description
Requirements Planning	Identifying user needs, existing workflow problems, and system objectives through observation and literature review.
User Design	Designing use-case diagrams, activity diagrams, and interface prototypes together with prospective users.
Construction	Building and coding the RIS module and integrating it with Orthanc PACS, followed by internal testing.
Cutover / Implementation	Expert validation, limited pilot testing with end users, revision, and preparation for wider deployment.

Source: Adapted from Martin, J. (1991). Rapid Application Development. Macmillan Publishing Co

Referring to the RAD stages above, the research procedure was operationalized into five sequential phases, summarized in Table 2.

Table 2. Research Procedure

Phase	Activities
1. Preliminary Study	Direct observation of the existing radiology workflow and a literature study on PACS and Orthanc implementation to identify usability gaps in the current system.
2. System Development	Preparation of use-case and activity diagrams, followed by construction of a demonstration prototype of the RIS integrated with Orthanc PACS.
3. System Validation	Black-box testing by three expert validators in health information systems and radiology, covering functionality, performance, user interface, security, compatibility, integration, error handling, and usability.
4. System Testing	Limited pilot testing at Ilyas Tarakan Naval Hospital using a pre-test (before development) and post-test (after development) usability measurement.
5. Dissemination	Reporting of results, presentation to hospital stakeholders, and publication of findings in a scientific journal.

Source: Developed by the author based on the RAD model adapted from Martin, J. (1991). Rapid Application Development. Macmillan Publishing Co.

The conceptual framework of this study compared two independent variables, namely the existing paper-based radiology expertise-reporting system and the developed RIS based on Orthanc PACS, with two dependent variables, namely system effectiveness and reliability. The framework examined how these two radiology data-management approaches influenced outcomes related to efficiency and data-management quality.

Data Source and Research Subjects

Data were gathered through a multidimensional approach comprising observation, interviews, and literature review. Primary data were obtained from two categories of subjects: three expert validators representing health information systems and specialist radiology, who assessed the product using black-box validation in the development phase; and ten end-user respondents from the Radiology Installation of Ilyas Tarakan Naval Hospital (including the head of installation, management staff, nurses, and radiographers), who completed a usability questionnaire before and after system implementation. Secondary data were obtained from relevant books and scientific journals.

Data Collection Technique and Instruments

Primary data were collected directly through an expert validation sheet completed during black-box testing, and through a structured usability questionnaire administered in a pre-test and post-test design. The main instruments used were a computer device for accessing digital references and managing data, a black-box validation instrument covering functionality, performance, user interface, security, compatibility, integration, error handling, and usability, and a Likert-scale questionnaire (Strongly Agree, Agree, Disagree, Strongly Disagree) measuring seven usability dimensions: Learnability, Efficiency, Effectiveness, Errors, Satisfaction, Privacy, and Design.

Validity and Reliability

Instrument validity refers to the extent to which a measurement tool accurately assesses what it is intended to measure, particularly for the items contained in a questionnaire; to achieve this, an instrument is validated by expert judgment (Dyah., 2018). The expert-validation instrument used in the system-development stage applied black-box testing, while the respondent questionnaire used in the evaluation stage was assessed through item-validity and reliability analysis prior to use.

Data Analysis Technique

Univariate analysis was used to explore each research variable. Categorical data were summarized through frequency distribution and relative percentage, while numerical data were described using measures of central tendency (mean, median) and dispersion (standard deviation). Bivariate analysis was applied to examine whether a real difference existed between conditions before and after implementation of the RIS based on Orthanc PACS. Pre-test and post-test scores were compared through the following sequence: a normality test (Kolmogorov-Smirnov and Shapiro-Wilk) to determine data distribution; a parametric difference test (paired t-test) if the data were normally distributed; a non-parametric difference test (Mann-Whitney/Wilcoxon signed-rank test) if the data were not normally distributed or the sample was small; and interpretation of results by comparing the resulting p-value with the significance level ($\alpha = 0.05$).

Table 3. Research Variables, Operational Definitions, and Measurement Scale

Variable	Operational Definition	Measurement	Scale
Paper-based radiology expertise-reporting system (independent)	A system managing radiology data using a traditional, paper/film-based method.	Likert-scale usability and efficiency questionnaire	Nominal
RIS based on Orthanc PACS (independent)	A system managing radiology data using PACS technology and open-source Orthanc.	Likert-scale usability and efficiency questionnaire	Nominal
System effectiveness (dependent)	Respondents' assessment of system efficiency, accuracy, and satisfaction.	Pre-test and post-test questionnaire	Nominal
System reliability (dependent)	Assessment of system stability, dependability, and performance during use.	Expert validation using the black-box method	Nominal

Source: Adapted from Heeks, 2006; Nielsen, 1993

RESULT AND DISCUSSION

Ilyas Tarakan Naval Hospital (RSAL Ilyas Tarakan) is a strategic health-service facility under the Indonesian Navy (TNI AL), located in Tarakan, North Kalimantan. Its Radiology Installation currently provides conventional and digital radiography, computed tomography (CT), ultrasonography, and mammography. Direct observation and interviews revealed that, despite this modality development, the installation does not yet have an integrated Radiology Information System (RIS) and Picture Archiving and Communication System (PACS); as a result, patient registration, examination scheduling, and result reporting are still performed manually with a high potential for error and inefficiency.

Without a PACS, radiology images are managed through physical media such as film and CD or stored temporarily on individual modality consoles (DR, USG, and CT), whose limited internal capacity often forces staff to delete older patient image data. This practice creates medicolegal risk because important medical data that may later be needed for follow-up treatment or legal purposes can be permanently lost. The absence of RIS and PACS also constrains the hospital's ability to integrate with a broader Hospital Information System (HIS) and to implement an electronic medical record (EMR), because imaging data—an essential component of the patient record—is not yet available digitally. Diagnostic results are currently communicated informally through Telegram in JPEG format rather than native DICOM, which slows the reporting turnaround and compromises image fidelity for archival purposes. These findings confirm an urgent need for an integrated RIS-PACS solution capable of transforming the radiology workflow into one that is more efficient, reliable, and patient-centered.

System Development: Architecture and Product Model

The development stage translated the recommendations from the preliminary study into a working product. Development began with mapping the existing workflow and reviewing best practices for RIS-PACS implementation, followed by construction of use-case and activity diagrams that define actor interaction and business-process flow. This development specifically targeted three factual problems: fragmentation of information systems and dependence on manual processes; limited internal modality storage leading to forced data deletion; and inefficient result distribution with limited digital accessibility.

The chosen solution was a purpose-built RIS integrated with an open-source PACS, using Orthanc as the core architecture. Orthanc was selected for its cost-effectiveness, customization flexibility, robust DICOM compliance, and availability of a RESTful API that simplifies integration with the RIS, making it a suitable option for a naval hospital with limited budgetary resources while still ensuring quality and interoperability. The recommended workflow begins with Patient Registration, in which patient data is entered into the RIS. The RIS then distributes patient information to the modality through the Modality Worklist (MWL) protocol, enabling automatic population of patient data on the modality console and eliminating manual re-entry, which was previously a major source of patient misidentification and protocol error. After the examination is completed, the modality automatically transmits the resulting images to Orthanc PACS for centralized storage and management through the SCP/SCU service.

Physicians access the stored images through a web-based DICOM viewer connected directly to the PACS, and after interpreting the images they enter an expertise report that is relayed back to the RIS. The radiographer/administrator manages the workflow to ensure the report is distributed promptly to the referring physician or patient. The overall system logic can be summarized using an Input-Process-Output (IPO) perspective, presented in Table 4.

Table 4. Input-Process-Output (IPO) Model of the Developed RIS-PACS System

Input	Process	Output
Patient registration data (demographics, examination type, schedule)	RIS-PACS integration through Modality Worklist (MWL); automatic worklist generation and distribution to modality; centralized DICOM storage in Orthanc PACS	Digitally generated expertise reports
Examination scheduling parameters	Automated transfer of examination images from modality to PACS; elimination of manual data entry at the console	Image and report sharing to support clinical decision-making

Source: Developed by the researcher based on the system design and workflow analysis at Ilyas Tarakan Naval Hospital, 2024

The RIS interface and business logic were built using the Laravel framework with a Bootstrap front end, while data are managed in a MySQL database chosen for its query optimization, scalability, reliability, strong data security, ease of management, and lower operating cost compared with alternative database engines. The developed modules include master-data management, integrated patient and order management linked to the Modality Worklist, digital diagnostic reporting with an embedded DICOM viewer, and a real-time monitoring dashboard. From a storage-management perspective, Orthanc was configured with a hybrid approach that combines local high-speed storage for recent examinations with archive storage for long-term retention, supported by automated compression to optimize storage utilization without compromising diagnostic image quality. Orthanc's built-in web viewer allows clinicians to access medical images from various locations within the hospital using existing computer infrastructure, avoiding the significantly higher cost of dedicated diagnostic workstations.

System Validation

Validation of the RIS based on Orthanc PACS was conducted carefully by three expert validators selected for their in-depth knowledge of health information systems, particularly in radiology, and their relevant experience developing similar systems. Testing used the black-box method, in which validators explored and interacted directly with the system without needing to understand its internal code structure. The assessment covered eight aspects: general functionality, performance, user interface, data security, compatibility, integration, error handling, and usability, with each item scored as Valid (1) or Not Valid (0) and the results tabulated into a validity percentage, as summarized in Table 5.

Table 5. Summary of Expert Validation Results

Tested Aspect	Items	Validity	Description
General Functionality	3	100%	Valid
Performance	3	100%	Valid
User Interface	2	100%	Valid
Data Security	3	100%	Valid
Compatibility	3	100%	Valid
Integration	3	0%	Not valid (hospital policy constraint)
Error Handling	3	100%	Valid
Usability	3	100%	Valid

Source: Primary data from black-box validation by three expert validators, 2024

Table 5 shows that seven of the eight tested aspects achieved 100% validity, confirming that the system's core functionality, performance, interface, security, compatibility, error handling, and usability meet the expected quality standard and require no further revision. The Integration aspect was the only exception, returning 0% validity; this did not result from an internal system failure but from the hospital's internal policy, which had not yet granted permission for direct integration testing with the existing patient-data system. This precautionary decision was intended to minimize the risk of data inconsistency during an initial integration and testing phase, and the aspect is expected to become a priority once further coordination and approval from hospital management are obtained.

System Testing

System testing directly involved end users in the Radiology Installation to compare usability before and after implementation. Ten respondents participated, consisting of four men (40%) and six women (60%), all from Ilyas Tarakan Naval Hospital, with the largest group being radiographers (4 respondents, 40%), followed by the head of installation, management staff, and nurses (2 respondents/20% each), as summarized in Table 6.

Table 6. Characteristics of Respondents (n = 10)

Category	Classification	n	Percentage
Sex	Male	4	40%
	Female	6	60%
Institution	Ilyas Tarakan Naval Hospital	10	100%
Position	Head of Installation	2	20%
	Management Staff	2	20%
	Nurse	2	20%
	Radiographer	4	40%

Source: Primary data from pre-test and post-test questionnaire respondents at Ilyas Tarakan Naval Hospital, 2024

Respondents were dominated by radiographers, reflecting the group most directly involved in daily radiology service delivery and therefore best positioned to provide information relevant to the study's objective. Usability was measured using a pre-test (before system development) and post-test (after implementation) covering seven dimensions:

Learnability, Efficiency, Effectiveness, Errors, Satisfaction, Privacy, and Design. The aggregated mean scores for each dimension are presented in Table 7.

Table 7. Mean Usability Scores Before and After System Implementation

Usability Dimension	Pre-test (Mean)	Post-test (Mean)	Change
Learnability	7.5	9.0	+1.5
Efficiency	7.1	9.0	+1.9
Effectiveness	7.7	8.9	+1.2
Errors	7.6	8.6	+1.0
Satisfaction	7.7	9.4	+1.7
Privacy	7.9	8.6	+0.7
Design	7.5	9.1	+1.6

Source: Primary data from pre-test and post-test usability questionnaire at Ilyas Tarakan Naval Hospital, 2024

An increase was observed in every dimension after implementation of the new system. Learnability, Efficiency, Effectiveness, and Satisfaction showed the most consistent improvement, indicating that the system became easier to learn, more efficient, more effective, and more satisfying to use. The Errors dimension improved as well, suggesting fewer mistakes once respondents became familiar with the system, while Privacy and Design also showed gains, reflecting better acceptance of data protection and visual design after the second evaluation.

To determine whether the improvement was statistically significant, pre-test and post-test scores were analyzed using normality, homogeneity, and Mann-Whitney tests, summarized in Table 8.

Table 8. Statistical Test Results of Pre-test and Post-test Scores

Condition	Normality (p)	Homogeneity (p)	Mann-Whitney (p)
Pre-test	0.238	0.055	0.000
Post-test	0.056	-	-

Source: Primary data analysis, 2024

The normality test showed $p = 0.238$ for the pre-test and $p = 0.056$ for the post-test (both $p > 0.05$), indicating that both sets of scores were approximately normally distributed, although the post-test value was close to the significance threshold. The homogeneity test produced $p = 0.055$ ($p > 0.05$), indicating homogeneous variance between the two conditions. Given the relatively small sample size ($n = 10$) and the post-test normality value approaching the 0.05 boundary, a non-parametric Mann-Whitney test was applied as a more conservative and robust approach; the result, $p = 0.000$ ($p < 0.05$), indicates a statistically significant difference between the pre-test and post-test scores, confirming that the intervention produced a real effect on respondents' usability perceptions.

Qualitative feedback from respondents was largely positive: the new system was described as having a more modern interface, a layout that eases navigation, and more systematic data management. Users reported that the system made it easier to access medical images such as radiology results through the DICOM application, accelerated the examination process, and simplified image retrieval and printing, while system speed, faster patient service, and easier recovery of lost data were noted as key added benefits. At the same time, respondents identified several shortcomings that still require improvement: an adaptation period was needed to learn the new system, particularly for less familiar users; the requirement to log in through a web browser was seen as cumbersome and potentially slowing access during emergencies; large DICOM file sizes created difficulty for some users; the absence of an automated backup system created a risk of data loss; the website design was considered less appealing; and unstable internet connections were a recurring concern. As improvement suggestions, respondents proposed a temporary offline-access feature, optimization for slow connections, internal notification and comment features among medical staff to speed communication, and better management of DICOM storage capacity on modality devices such as X-ray units.

The preliminary findings showing continued dependence on paper-based workflows, information fragmentation, and limited digital storage mirror challenges reported in many developing-country hospitals that are only beginning their digitalization journey; reliance on paper-based systems is consistently identified as a major barrier to achieving data efficiency and accuracy in health facilities (Al-Dubai & Gan & Al-Naggar R. A., 2019). The absence of an integrated RIS meant patient information had to be entered manually at every stage, from registration to the modality console, wasting valuable staff time and increasing the risk of patient misidentification and examination-protocol error. Furthermore, the lack of a centralized PACS forced reliance on physical media and modality-internal storage, echoing the literature's emphasis on PACS as a safe and centralized solution for digital image storage and management (Franken & Smith W. L., 2007). The resulting fragmentation also hampered integration with a broader Hospital Information System, consistent with findings that a lack of interoperability among information systems is a primary factor limiting the quality and efficiency of health services (Kushniruk & Borycki & Lau F., 2019).

The architectural choices made during development align with established software-engineering practice, which emphasizes a thorough understanding of the problem domain before implementation (Pressman, 2020). Selecting Orthanc as the PACS core was justified by its cost-effectiveness, DICOM compliance, and RESTful API, characteristics documented as core strengths of the platform for supporting modern radiology workflows (D’Onofrio, 2019; Jodogne, 2018). Integrating the RIS and PACS through a Modality Worklist protocol directly eliminated manual data entry at the modality console, a key source of error and inefficiency in the previous workflow; this is consistent with prior findings that MWL implementation meaningfully improves radiology workflow efficiency (Chung, 2017). The choice of MySQL as the underlying database was similarly guided by its balance of reliability, security, manageability, and cost-effectiveness relative to alternative database platforms (Sidharta & Wibowo T., 2020).

The validation results indicate that the system has reached a high level of functional maturity: seven of the eight tested aspects achieved full validity, suggesting that the fundamental design and development already meet the expected quality standard. The single exception—integration testing—reflects an organizational and policy constraint rather than a technical shortcoming, which is consistent with evidence that the success or failure of health information technology implementation is frequently determined by organizational and governance factors rather than technology performance alone (Blijleven, 2017). This finding underscores that further coordination with hospital management, rather than additional system redevelopment, is the primary requirement for completing full integration testing in the future.

The significant improvement across all seven usability dimensions after implementation supports the effectiveness of the RAD-based development approach in producing a system that end users find easier to learn, more efficient, and more satisfying than the previous manual workflow. The use of a non-parametric Mann-Whitney test, despite indications of approximate normality, was a deliberate methodological choice appropriate for small-sample, quasi-experimental designs, where a more conservative test reduces the risk of a false-positive conclusion (Cook & Campbell D. T., 1979). The positive qualitative feedback—particularly regarding faster access to DICOM images, more systematic data management, and reduced service time—reinforces literature findings that well-designed radiology information systems can materially improve workflow efficiency and staff satisfaction (Wickramasinghe & Bali R. K., 2007). Conversely, the challenges reported by respondents, such as the learning curve for new users, web-login friction during emergencies, large DICOM file sizes, and dependence on stable internet connectivity, are common obstacles in health-information-system implementation across facilities with varying levels of IT infrastructure maturity (Ammenwerth, 2019). The fact that respondents were able to articulate specific, actionable suggestions—offline access, bandwidth optimization, and internal communication features—illustrates the value of an iterative, feedback-driven development process, which is widely recognized as a key determinant of sustained success in health-information-system implementation (Grol & Wensing M., 2004).

Taken together, these findings suggest that an open-source RIS-PACS built with a structured RAD approach can substantially improve radiology workflow efficiency and usability at a fraction of the cost of commercial alternatives, while highlighting that full realization of an integrated digital ecosystem ultimately depends on parallel progress in hospital governance and infrastructure readiness.

CONCLUSION

The Radiology Information System (RIS) based on Orthanc PACS at Ilyas Tarakan Naval Hospital was successfully designed and developed to address information fragmentation, reliance on manual workflows, limited DICOM storage capacity, and inefficient result distribution. The system integrated a Laravel- and Bootstrap-based RIS with the open-source Orthanc PACS through a Modality Worklist mechanism that automatically transferred examination images from Digital Radiography (DR), ultrasound (USG), and computed tomography (CT) modalities into centralized and scalable storage. This integration reduced the risk of console-level storage overflow and the need for forced deletion of older patient data. The centralized digital archive provided the structural foundation to support the five-year medical record retention requirement stipulated in the Regulation of the Minister of Health of the Republic of Indonesia Number 269 of 2008; however, compliance with the five-year retention period was not directly evaluated within the scope of this study.

Expert validation confirmed 100% validity across seven of the eight evaluated aspects, while the integration aspect could not be fully assessed due to internal hospital policy constraints rather than technical limitations. Pilot testing demonstrated statistically significant improvements in usability across all seven measured dimensions (Mann–Whitney $p = 0.000$), indicating that the system was effective and appropriate for implementation in a budget-constrained type D hospital. It is recommended that Ilyas Tarakan Naval Hospital implement a phased and modular integration of the RIS-PACS with its existing Hospital Information System using open standards, establish an efficient DICOM backup strategy such as hybrid cloud storage or a Network Attached Storage (NAS) with Redundant Array of Independent Disks (RAID) configuration, and further develop high-impact features identified by users, including real-time notifications and temporary offline access, using internal or open-source resources to improve workflow efficiency and overall user experience.

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