Development of a System for Transmitting Medical Data and Diagnostic Images via the Internet for Hospitals in Thailand

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Abstracts: This research project aims to advance healthcare data and diagnostic imaging delivery by employing a digital Picture Archiving and Communication System, also known as PACS, alongside a web application that is internet accessible. The study explores two main areas, which are User Interface design and system functionality. The User Interface design merges the aesthetic of traditional paper documentation with the advantages of electronic displays to enhance both readability and overall user experience. The system functionality has been assessed and confirmed to offer secure and efficient transmission of medical diagnostic data as well as radiographic images. By complying with the Personal Data Protection Act of 2019 or PDPA, the system ensures the safe handling of confidential personal information. Test results show that the system meets performance standards and has been well-received by users. The project serves as a timely solution for today's medical industry, focusing on the speed and security of diagnostic data and image transmission.

Keywords: Cloud PACS, PACS System, DICOM, Online PACS.

1. INTRODUCTION

Database technology is rapidly gaining prominence in healthcare systems, both in Thailand and globally. A surge in the adoption of digital database systems is noticeable, predominantly to reduce paper-based documentation and eliminate repetitive tasks and redundant data entries. Advancements in medical imaging technologies such as Spiral Computed Tomography, Digital Subtraction Imaging, Color Doppler Ultrasound, and Computed Radiography (CR System) have facilitated a transition to the DICOM standard for image storage [1]-[3].

Traditionally, the dissemination of radiological diagnostic data in Thailand has been carried out through physical means, including CDs, film, and paper records. This approach demands manual delivery, often conducted by healthcare workers, relatives of patients, or even the patients themselves. Such methods pose inherent risks, including data loss, damage, and unauthorized access, potentially leading to the improper dissemination of sensitive medical data [4]-[8]. In cases demanding urgent attention, some healthcare institutions resort to readily available online platforms such as Line applications and Facebook Messenger for transmitting diagnostic data. Despite their convenience, these platforms do not meet the stringent security requirements for handling medical data, thus compromising the integrity and confidentiality of this critical information [9]-[15].

This study aims to introduce a secure, web-based platform designed for the transmission of medical images and diagnostic data among healthcare institutions in Thailand. The proposed system places a strong emphasis on both secure data storage and effective control of data accessibility. Compliance with Thailand's Personal Data Protection Act (PDPA) is rigorously maintained throughout the system's architecture [16]-[19]. In order to evaluate the system's performance and gauge user satisfaction, comprehensive tests and surveys have been carried out. These evaluations underline the importance of robust security protocols and a strong commitment to individual privacy rights in the development of healthcare database systems. Moreover, this research delves into the development process of a Picture Archiving and Communication System (PACS), ensuring it meets user requirements while aligning with Thailand's PDPA [19]. The study highlights the pivotal role such technology plays in advancing healthcare data management while also safeguarding individual privacy rights. Additionally, the research explores

the integration of AI technologies for advanced medical image processing [20]-[23].

2. RESEARCH METHOD

2.1. Research Overview

In designing an internet-based system for transmitting medical diagnostic data and images for hospitals in Thailand, the design process includes establishing a database system, as illustrated in Figure 1. The design process involves studying the data system that must capture images from medical devices, understanding relevant PDPA laws within the country, examining standard file formats, converting medical device-generated images into standard DICOM files, researching centralized cloud storage systems, designing the database system according to the studied data conditions, testing the database system, evaluating the system with experts and users, and summarizing the results of the system implementation.

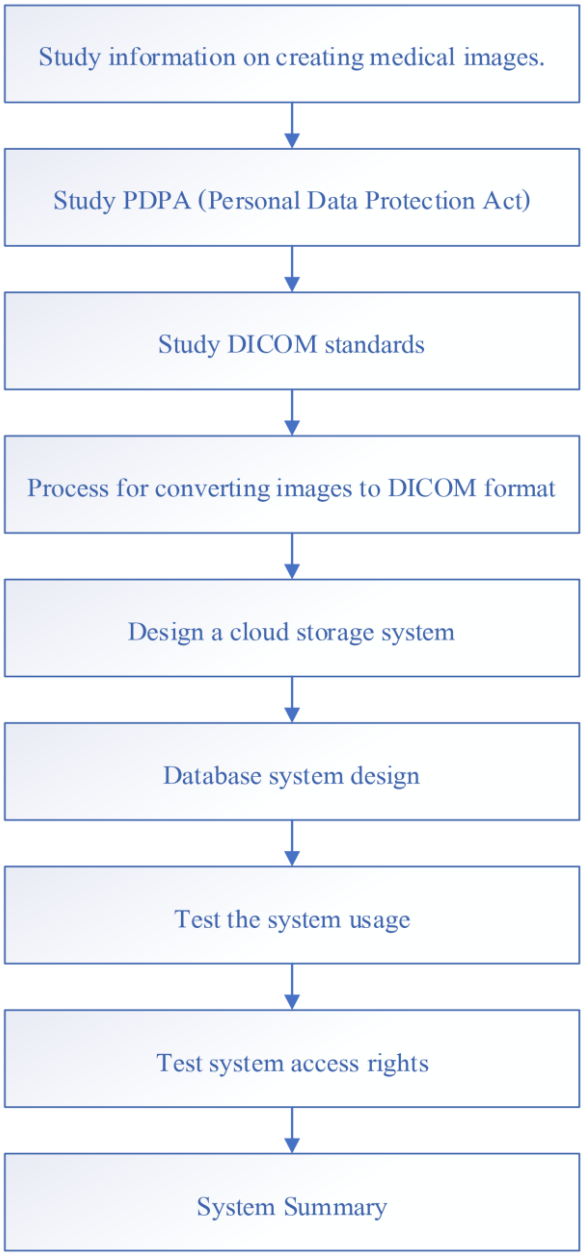

Figure 1. Overview of the Principles of Database System Design Presented in Thailand.

The usage of the system is illustrated in Figure 2, showing the database functionality of the designed system. Users must log in to access the system. If they do not have an account, they will have to register first. Afterwards, the system administrator will review and set permissions based on the user's role. Once logged in, users can view and edit patient information according to the PDPA guidelines for each patient, and in accordance with the cases they are responsible for treating. Furthermore, images uploaded using medical equipment will be converted into the standard DICOM file format.

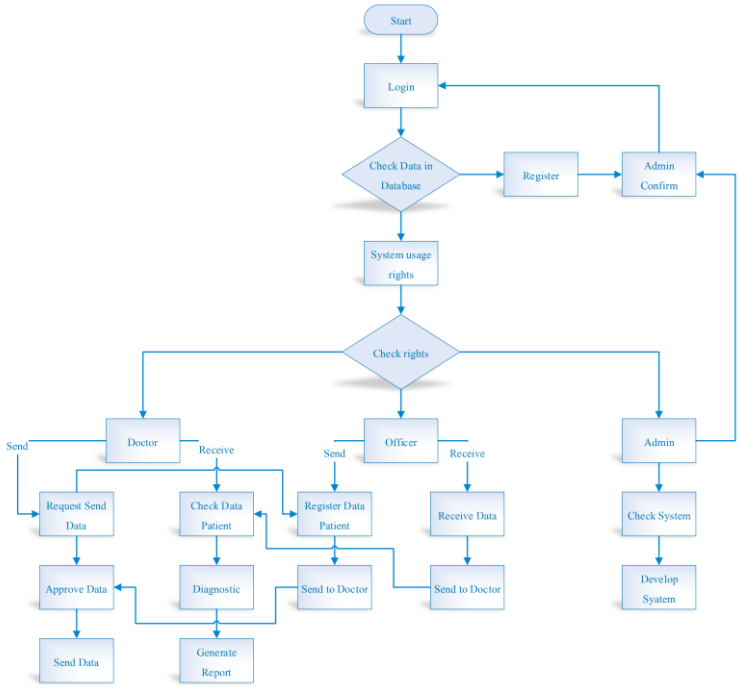

Figure 2. Overview of the Functionality of the Designed Database System.

2.2. Picture Archiving and Communication System

The Picture Archiving and Communication System (PACS) serves as an integral solution for managing, transmitting, and archiving medical images and associated data across computer networks. Utilizing the DICOM standard, this system ensures the secure and efficient transfer of medical images and information. The primary architecture and functionality of this digital healthcare data management system can be further understood by referring to Figure 3.

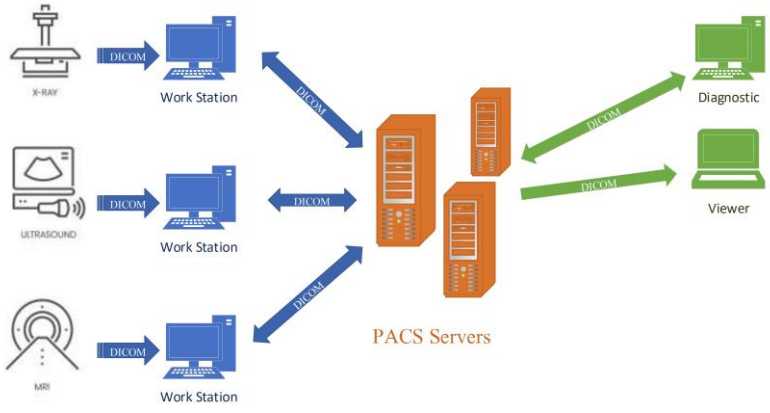

Figure 3. Principles of Operation for the Medical Image Archiving and Digital Data Transmission System.

The core operation of the PACS focuses on storing medical or radiographic images and facilitating digital data exchange within the radiology department. This system can integrate with a diverse range of devices that comply with the DICOM standard. Examples include Spiral Computed Tomography, a specialized X-ray machine utilizing computer technology; Digital Subtraction Imaging, another X-ray device that employs radiopaque substances primarily for gastrointestinal examinations; Color Doppler Ultrasound, which uses high-frequency sound waves to analyze blood flow conditions; and Computed Radiography (CR System), an X-ray machine that employs Imaging Plates instead of traditional film for digital image capturing.

All images produced by these devices are in digital format and can be stored directly into the PACS database. These digital images can also be disseminated to various service points across the hospital. Devices already using digital technology and conforming to the DICOM standard can seamlessly integrate with the PACS system for real-time data sharing. In specific cases where patients require their radiographic images for continued treatment at different healthcare facilities, the PACS allows for image printing via specialized radiographic printers connected to the system. Additionally, patients have the option to receive these images in the form of compact discs, eliminating the need to carry multiple traditional films for ongoing treatment.

2.3. Personal Data Protection Act B.E. 2562 (2019)

The Personal Data Protection Act B.E. 2562 (2019), commonly known as PDPA, serves as Thailand's cornerstone legal framework for safeguarding the personal data of individuals and legal entities. This comprehensive legislation stipulates a range of civil, criminal, and administrative penalties for non-compliance.

In our increasingly interconnected digital world, the secure management of personal data has never been more critical. This data often circulates through various online platforms, from e-commerce sites to job application portals. Given the significance of data protection, organizations must not underestimate the complexity of compliance with the PDPA. Executives and organizational leaders should prioritize regular oversight and proactively implement measures to mitigate legal risks. Failing to secure or appropriately manage personal data can lead to severe consequences, including legal penalties and lasting damage to the organization's credibility and trustworthiness.

2.4. Advancements in Cloud-Based PACS Integration with Customizable Forms for Radiology Research and Education

The research topic, led by Jason Hostetter and his team in 2018 [24], focuses on the integration of cloud-based PACS that operates without patient-identifiable information. The system also incorporates customizable forms for use in radiology research and education. This unique approach allows medical images to be displayed via a web browser without the need for additional software installation.

The developed PACS Viewer can be accessed through web browsers and is compatible with both desktop computers and various portable devices that support web browsing. Cutting-edge technologies such as HTML5, Canvas and JavaScript have been employed in conjunction with the open-source Cornerstone library to create a web application. The results of this research have been groundbreaking. They have led to the creation of more effective educational modules and tools that enhance the efficiency in managing medical images for both educational and research purposes. Images uploaded to this cloud based PACS system do not include any patient data, serving to enhance the security and privacy of the diagnostic process. This particular feature ensures that sensitive patient data are not compromised, maintaining the highest standards of privacy and security in radiology practice.

This research represents a significant advancement in the field of radiology by making medical imaging more accessible, while also prioritizing privacy and security. It sets a new standard for how medical images can be managed and accessed, promoting both the advancement of medical research and the safeguarding of patient confidentiality.

3. SYSTEM DEVELOPMENT DESIGN

System development begins with an exhaustive study and review of the merits and drawbacks of currently operational systems. Based on these observations, the data are consolidated and analyzed to design the workflow, database structure, and user interface of the new system.

3.1. Workflow Design for System Operations

The initial phase includes gathering patient history and medical image data from existing hospital information systems. This information is integrated into a patient transfer system, which allows for the initiation of patient handoff procedures. Figure 4 demonstrates the workflow, detailing how medical images are stored. The data are archived in standard DICOM (Digital Imaging and Communications in Medicine) format before being transferred to a centralized database. Access to this system is extended to hospitals of various sizes—small, medium, and large.

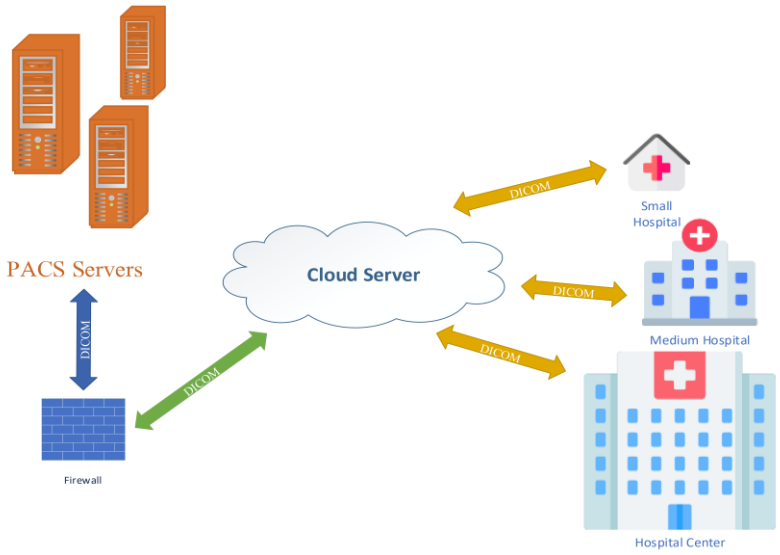

Figure 4. illustrates the designed workflow of the system.

3.2. System Structure Design

The design of the system structure is a comprehensive process that focuses on various facets including data management, data set relationships, data retrieval, and appropriate user interface (UI) design to meet user requirements and enhance system performance for future iterations. The connection to the database is depicted through a context diagram, which highlights the interrelations between the database and other systems. Workflow diagrams emphasize the sequence and processes that the system will undertake or that flow from other systems. The Database Design section elucidates the structure of the database, including tables, fields, and conditions for linking tables. Finally, the UI design is segmented into two main areas—screens for general users and screens for system administrators. This design approach not only aims to improve user experience and system performance but also sets a standard for the development of future systems.

3.3. Steps in System Development and Testing

This section outlines the blueprint for system development, starting from database creation, programming, to system testing. The design details for system development and testing are illustrated in Figure 5. The development phase is divided into five stages, each comprising development, trial runs, problem listening, and subsequent system adjustments until a comprehensive system is achieved, which can then be deployed in healthcare settings.

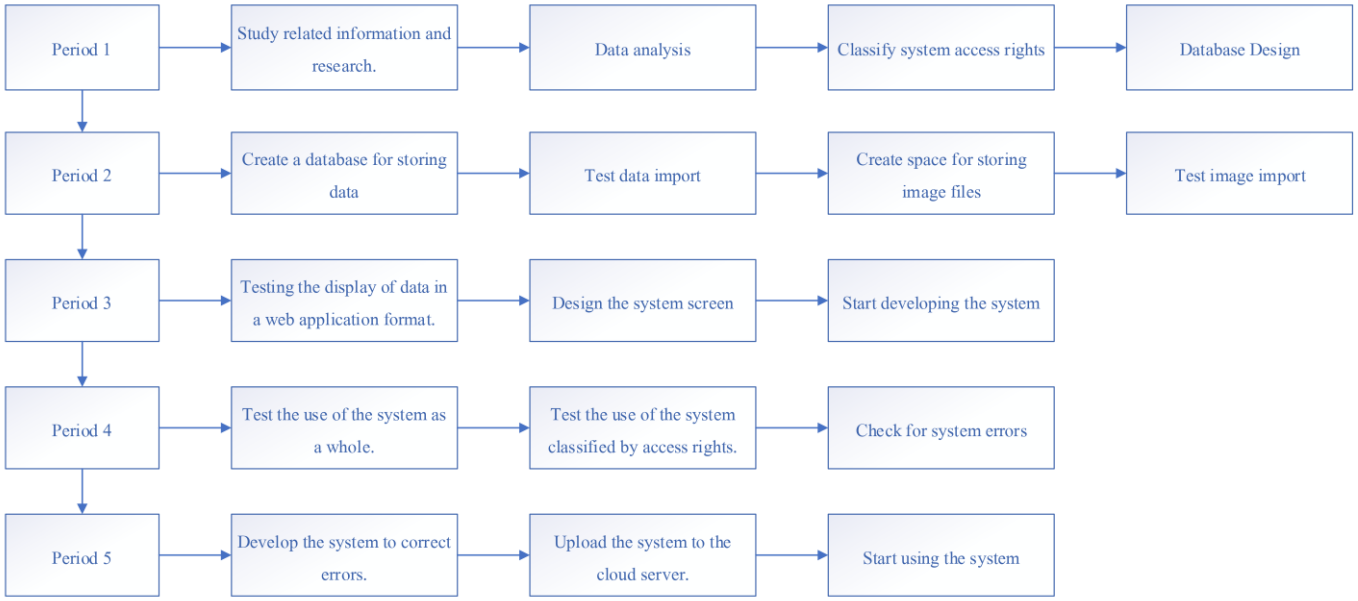

Figure 5. illustrates the steps involved in system development and testing.

In this iterative process, each stage is critical for identifying gaps, improving system functionality, and assuring that the final product aligns with the healthcare environment's requirements. Such a multistage approach ensures that the system is robust, efficient, and adaptable for future needs.

3.4. Design Access and User Permissions for the System

The design of user permissions and data access is a crucial element in controlling and managing system data. Access levels are divided into various tiers based on roles and responsibilities within the system. For physicians, permissions grant access to patient data, view diagnostic images, and confirm diagnosis. Staff members can input patient data and conduct preliminary data verification before forwarding the information for physician approval. Meanwhile, system administrators have the authority to manage user permissions, add new users, inspect errors, and make system adjustments to maintain operational readiness.

The design of this multi-tiered access and permission framework enhances both the security and efficiency of the system over the long term. By ensuring that each user role has access only to the data and functionalities necessary for their job, the system minimizes the risk of unauthorized data access or alteration, while streamlining operations to be more efficient.

3.5. System Usability Testing Design

During this stage, the focus is on constructing a usability testing strategy that closely mimics real-world scenarios. The aim of this testing is to validate whether the developed system meets the research objectives in terms of both its functionality and access rights granted to users. This entails segmenting users according to their respective permissions, verifying that the system functions as intended. The testing process is visually outlined in Figure 6, which features a block diagram detailing the system's testing steps.

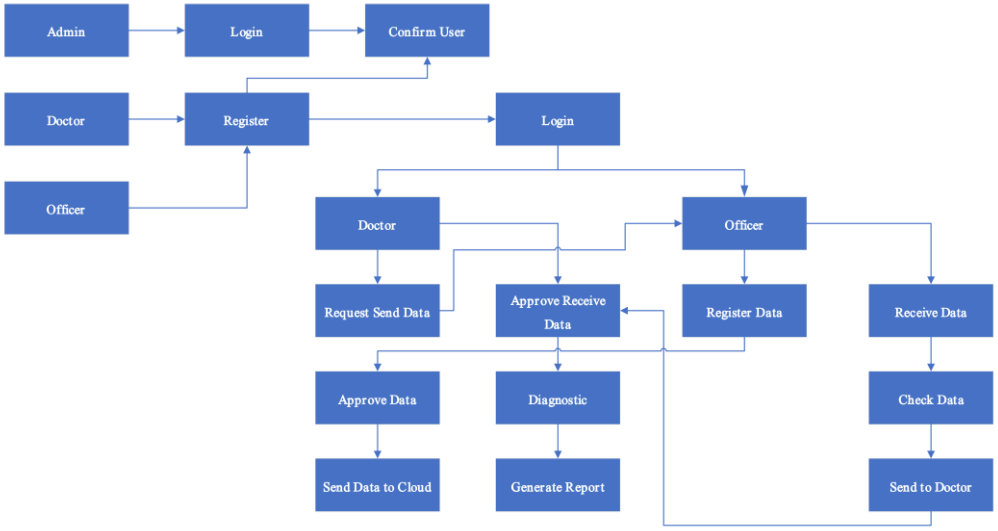

Figure 6. illustrates the system testing process using a block diagram.

4. SYSTEM DESIGN OUTCOMES

In this research project, the system's design and testing results are bifurcated into two main segments. The first segment focuses on the User Interface (UI) design, which is illustrated through Figure 7 to Figure 10. The second segment is dedicated to functionality testing, which evaluates the system's ability to securely transmit medical data and images via a web application. It also assesses the user access permissions to confirm that they align with the initial design and predefined objectives. These results are collectively summarized in Table 1.

4.1. Design of the UI Screen

In this section, the system's interface is displayed through a series of figures, each illustrating a key aspect of its design. Figure 7 highlights a login screen optimized for both security and user friendliness. Figure 8 turns the spotlight to the display of patient details, and Figure 9 offers an interface for medical image viewing. Figure 10 features the patient referral registration screen, while Figure 11 presents the screen for confirming patient referral.

These figures collectively serve to underline the UI design of the database system, with a strong emphasis on readability and simplicity. The design successfully integrates the familiarity of traditional paper documentation with the functionality of electronic displays.

In summary, the design across these four figures prioritizes a user experience that is streamlined and easy to read, effectively combining the formality of traditional paper documents with the advantages of electronic mediums.

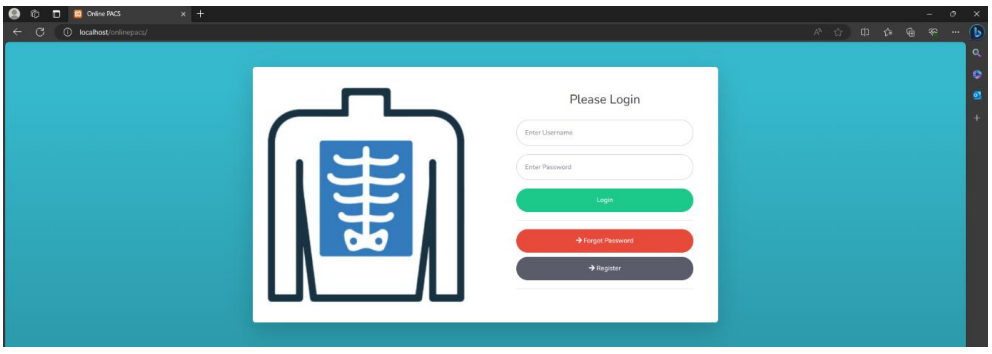

Figure 7. Shows the login screen which is designed for security and user friendliness.

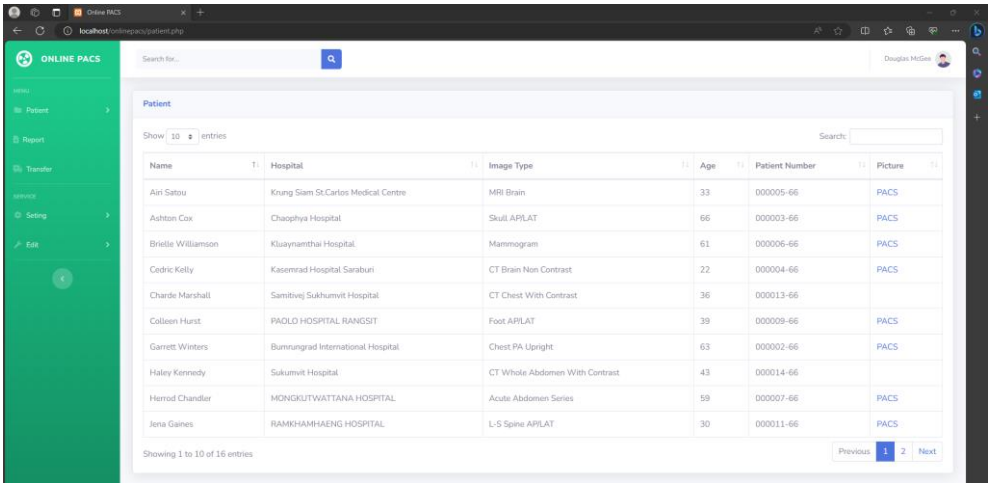

Figure 8. Focuses on presenting patient details.

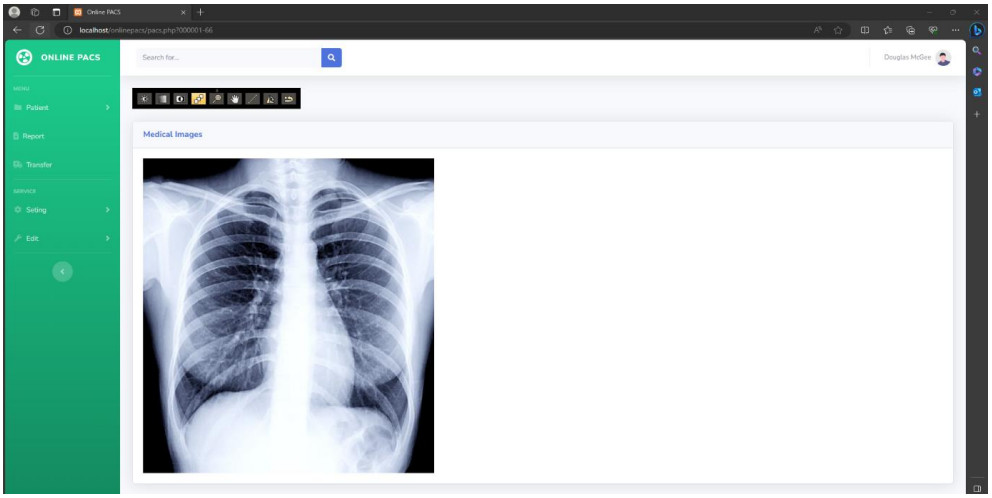

Figure 9. Offers a platform for viewing medical images.

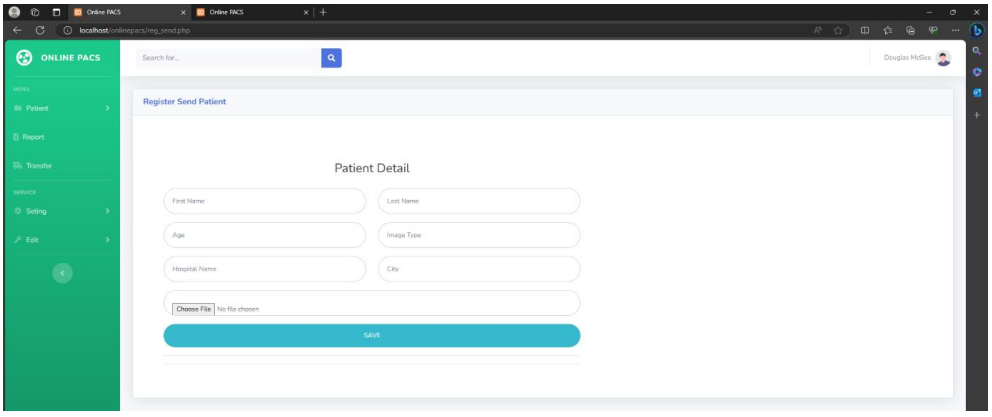

Figure 10. Displaying the Registration Screen for Patient Referrals.

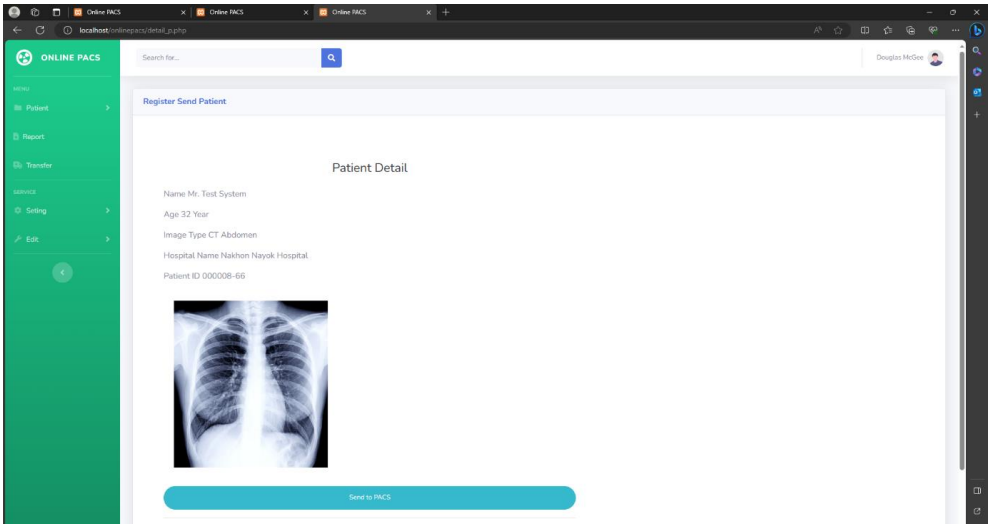

Figure 11. Displaying the Screen for Confirming Patient Referrals.

4.2. System Access Test Evaluation Results

The system tests indicate that its functionalities align well with the initial objectives. This is evident from the successful exchange of patient data, transmission of medical images, and the delivery of diagnostic information through web applications over the internet. It shows that the data can be both sent and received as needed and is accurate. In the aspect of system access, there are varying levels of data accessibility privileges depending on the user role, be it a doctor, a staff member, or an administrator. Doctors are granted access only to the data of the patients for whom they have authorization or whose care they are directly responsible for. Staff members can input patient data only when requested by a doctor and once entered, only the doctor can confirm the information. The doctor must personally submit the confirmed data into the system for it to be fully integrated. These access privileges are detailed in Table 1 below.

Table 1. Summary of database access and edit permissions for patient data

No.	Data Type	Doctor	Staff	Administrator
1	Patient Information	Access limited to designated or own patients	Can input upon doctor's request	Full access, compliance with PDPA required
2	Medical Images	Access limited to designated or own patients	Can input upon doctor's request	Full access, compliance with PDPA required
3	Patient Transfer Data	Access limited to own referrals	View-only after doctor's confirmation	Full access, compliance with PDPA required
4	Patient Admission Details	Access limited to designated or own patients	Initial filtering, no access after doctor confirms	Full access, compliance with PDPA required
5	User Account Information	Access to own account only	Access to own account only	Full access, compliance with PDPA required

In summary, the access privileges are effectively categorized, ensuring the accurate and secure handling of sensitive data in compliance with PDPA regulations.

CONCLUSIONS

This research project successfully employs digital technology and the internet to revolutionize the medical healthcare delivery system. Focused on improving patient convenience and reducing treatment time, the developed system embodies secure, digital storage of medical data. Key security features, such as data encryption, are embedded to protect sensitive patient information. Functionality testing corroborates the system's proficiency in secure and accurate data transmission, including medical images and diagnostic information. Different user roles, such as doctors, staff, and administrators, are meticulously designed to have varying levels of data accessibility, all in compliance with PDPA regulations. Moreover, the UI design is an amalgamation of traditional documentation's readability and the convenience of digital formats. The UI is crafted to be both user-friendly and efficient, thus facilitating a streamlined experience for all types of users. The project holds significant potential for scaling, particularly beneficial during epidemic situations. By making healthcare more accessible via the internet, it alleviates the challenges and risks associated with commuting to healthcare facilities. In scenarios like the ongoing COVID-19 pandemic, such systems can significantly lessen the burden on healthcare workers while enhancing patient care efficacy. In summary, this research project not only meets but potentially exceeds its initial objectives, offering a secure, convenient, and efficient medium for medical data handling and healthcare delivery. Future studies could focus on real-world implementation and further optimization to adapt to different healthcare settings and emerging patient needs.

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