

Development Of Web-Based *Teleradiology* Application To Enhance The Quality Of Radiology Services

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ABSTRACT. *The development of digital radiology technology improves the quality of medical services, but challenges in image distribution and interpretation encourage the use of teleradiology. The development of web-based teleradiology applications is a cost-effective solution with the ability to integrate patient data and DICOM image display to improve the efficiency of radiology interpretation. This has the potential to improve the quality of radiology services by accelerating the diagnostic process and reducing the physical accessibility limitations of radiologists. This study aims to develop a web-based application as a solution to radiographic image delivery and PACS weaknesses, and test its effectiveness in improving the quality of radiology services. The research method used is the research and development (R&D) method, which aims to produce and test new products. The results of this study show that the development of a web-based teleradiology application provides an appropriate solution to the constraints of the reader's presence at the image capture site, while maintaining image quality according to DICOM standards. The application allows easy use of various devices, data exchange between medical professionals, and secure data storage. In Addition, it reduces the waiting time in the delivery and reading of radiographic images by radiologists. Compared to older methods, such as delivery via email or Whatsapp, this web application shows improved quality and accuracy of radiographic image reading.*

Keywords: *Teleradiology, Web Application, DICOM, Radiology Technology*

INTRODUCTION

Digital radiology equipment produces various image forms including JPEG (jpg), DICOM, PNG (Portable Network Graphics), Graphics Interchange Format (GIF), Tagged Image File Format (TIFF). In addition, digital radiology equipment can also produce video or animation files in AVI (Audio Video Interleave) format or other formats, depending on the type of equipment and application used.

The images produced from digital equipment will be read to produce a diagnostic support by radiologists. Some of the medical images produced by digital tools in the radiology unit are Radiography (X-ray) Images, Computed Tomography (CT scan) Images, Magnetic Resonance Imaging (MRI) Images, and Ultrasonography (USG) Images, Positron Emission Tomography Images (PET scan). Reading images for radiology services can be done in two ways, namely direct and indirect reading. The direct reading method is a method involving a radiologist or radiology doctor who directly views and analyzes the radiographic image on a screen or physical print. Meanwhile, indirect reading involves the use of long-distance communication technology to transfer images of radiology services from one place to another, thereby allowing reading and interpretation by a radiology doctor who is not at the examination service location. We call readings like this teleradiology. In teleradiology, radiology service

images taken at one location are sent via a communications network to another location where radiologists view and analyze the images. This allows for fast and efficient consultation and interpretation even if the radiologist or doctor is in a different location.(1)

PACS is a digital imaging device used to obtain, process and store, distribute radiology examination results using the DICOM (Digital Imaging and communication in medicine) standard where DICOM is the world's standard file format for radiological images, the DICOM file format stores information about patient data and used as a diagnostic standard for reading radiological images (2) . With the expensive cost of developing PACS, several health service facilities have chosen to send radiographic images via WhatsApp and email so that radiology unit services can continue to run well in health service facilities that do not have a permanent radiology doctor who can be on standby in the radiology unit of the health service facility.(3)

Whatsapp is installed on the smartphone, where the smartphone is a device that is light and fast in displaying medical images so it is very helpful, especially in emergency cases, to immediately get interpretation results from radiologists. Through the WhatsApp application, users can send messages in the form of text, images, videos, contacts and more quickly and easily. This is what makes WhatsApp an option because the application is easy to use or user friendly. The image formats used in WhatsApp are Graphics Interchange Format (GIF), Joint Photographic Experts Group (JPEG), and Portable Network Graphics (PNG) (4).

Email is also an alternative that is currently used for sending images from radiology modalities, images that can be sent and received by email are JPG and DICOM, for JPG files the image can be viewed directly, but for DICOM files, email cannot display the image directly so need to download and move the DICOM image data to the DICOM viewer which will take time in the process of moving and opening the DICOM image(5).

Due to the shortage of ways to send radiographic images via WhatsApp and email, researchers created a web-based application to be a solution to the shortcomings of the way to send radiographic images and the weaknesses of PACS related to development costs (6). The web-based application is an application for sending data and storing data that is used as a medium for reading radiology service images remotely which is equipped with a viewer and supports DICOM files produced by digital radiology images. DICOM (Digital Imaging and Communication in Medicine) is the standard file format for Digital Radiology images throughout the world (7) so that all digital radiology equipment from various brands will use the DICOM file format. To open a radiology image file in DICOM format, a DICOM Viewer is required as a reading medium (8).

The web-based Teleradiology application is equipped with patient data and a DICOM Viewer, making it easier for radiologists to read the results. DICOM is a dynamic image file that can have contrast brightening characteristics, increase/decrease brightness and contrast, digital measurements will display a ruler menu that can be used according to measurement needs (for example measuring images of the heart, lesions, nodules), so that the displayed image can be adjusted to suit your needs. reading requirements for accuracy and reporting in real time. This will improve the quality of medical services, especially in radiology, as a solution to the physical absence of radiologists at the practice site and reduce the waiting time for radiographic image interpretation results. Teleradiology with a web-based application that will be developed has the ability to display medical images in DICOM format and has relatively low development costs. This research aims to design a web-based teleradiology application system in radiology services, determine the contribution of a web-based teleradiology system in speeding up the flow of radiology services, and compare the effectiveness of the web teleradiology system with previous methods to evaluate performance improvements.

RESEARCH METHODS

The design used in this research is the research and development (R&D) method. The purpose of this method is to produce a product and test the effectiveness of the product. This R&D research combines qualitative and quantitative approaches, after which the effectiveness of the product is tested using analytical methods, therefore this research is called mixed method research (MMR)(9). The research and application design procedure includes 5 main steps, namely as follows: 1) Product design, 2) Application testing, 3) Retrieval of data on the effectiveness of the teleradiology application compared to previous systems, 4) Capture and measurement of time duration using the web application and without using the application web, 5) Data processing and statistical tests on sample data. Respondents in this study were radiology administrators, radiographers and radiology doctors. The independent variables in this research are manual service systems and applications. The dependent variable in this study is the increase in the quality of radiology services after using the application.

RESULTS

1. Information Collection

Observation is the initial planning in this research. Observations were carried out by observing directly by observing the flow of radiology unit services in health service facilities. The results of the observations showed:

- a) Sending images of radiology services via the WhatsApp smartphone application was found to be prone to short periods of time but blurred image resolution occurred due to compression occurring automatically or directly from the WhatsApp application, so sometimes radiologists asked to resend them via email which had a higher resolution but still had the same JPG image form. .
- b) Sending images of radiology services via physical film resulting from digital images using radiology service modalities takes longer than sending images via WhatsApp and email applications, based on researchers' observations, reading interpretations like this really slows down the diagnosis, especially for emergency cases and requires supporting factors. others such as courier human resources, vehicles and other transportation costs

2. Design and Build a Web-Based Teleradiology Application System in Radiology Services

The results of the observations were used to improve the flow of image reading for radiology services from the old method to a web-based application created by researchers in order to achieve correct and appropriate goals. The product design steps in this research can be explained in a flowchart as follows:

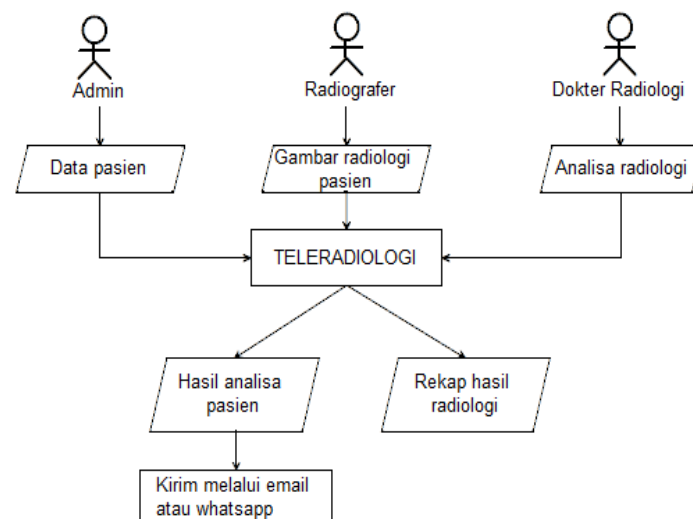


Figure 1 Flowchart of the teleradiology application

3. Product

Based on the teleradiology application flowchart which has been prepared considering the effectiveness and improvement of service quality, also based on the activity diagram of the medical image results, a design for the web-based teleradiology application has been

prepared. There are 3 types of users in one application with different displays based on the flowchart, namely radiographer users, radiologist users and admin users. Each type of user has different application management rights with different menus that can be accessed, making it easier to use the application.

a) Login View

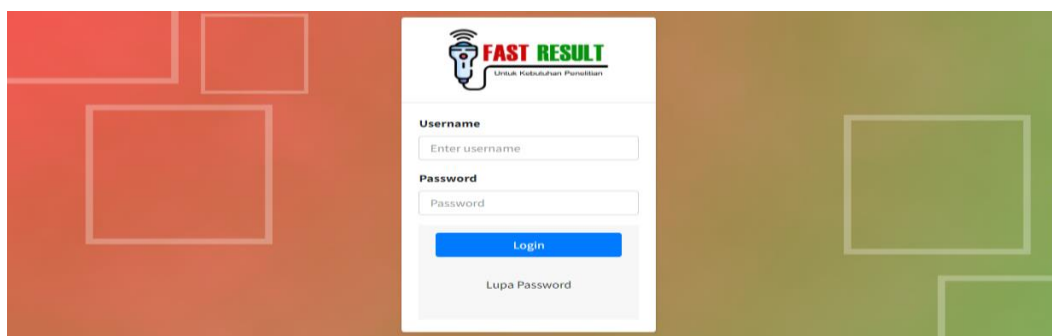


Image 2 Of The Start Page Of The Teleradiography Application

On the login page, enter your username and password. If the data entered is correct it will be processed to the start page.

On the home page the radiographer displays patient data. The initial page display structure includes a navigation bar or navbar menu, patient card menu, and patient data table. The navbar menu consists of home, Add DICOM, Add file, user, settings, recap, and logout. The menu on the menu card consists of total patients, not yet completed, draft results, and final results. The patient data menu consists of a delete button, search period, search column, and also a table.

4. Contribution of Web-Based Teleradiology Systems in Speeding Up the Flow of Radiology Services.

To carry out the implementation, we have carried out the implementation process on a cloud system with the following address: <https://fastresultmcu.com> where we have implemented a security code and also a security certificate in response to user suggestions and input. Https is a secure address using an SSL (Secure Socket Layer) certificate, which is a website's way of establishing a secure (encrypted) connection between the webserver (website) and the client (browser) or between the mail server and the mail client. So that the connection between the client and server can run safely from other unauthorized parties. The following is the application before and after using the teleradiology application:

Table 1 impact of implementation before and after using the teleradiology application.

No.	Alur Pelayanan Radiologi Lama	Alur Pelayanan Radiologi Dengan Penggunaan Aplikasi
1	Data entry by admin	Filling in patient data by admin
2	Image creation	Image creation
3	Image conversion from DICOM to JPG	Upload the resulting DICOM image
4	Sending results via email	Image analysis by a radiologist
5	Image analysis by a radiologist	There is already a result format
6	Sending interpretation results by radiologist to admin	Results can be sent directly via email/whatsapp
7	Typing the reading results according to the radiologist's interpretation	Recap of patient results data will be compiled automatically
8	Printing of reading results	
9	Handover to patient	
10	Recaps of patient results are still compiled manually	

In the flow of radiology services, the web-based teleradiology application system acts as a link that integrates each stage of the process effectively and efficiently. With the old radiology service flow, where each step was carried out separately and manually, the teleradiology application system changes the way of work to be more structured and automated. From filling in patient data to delivering results, everything can be done on one platform. The image creation and analysis process is carried out more quickly and accurately because DICOM images can be uploaded directly to the application. Interpretation results from radiologists can be delivered directly via email or WhatsApp without the need to wait for the printing process, speeding up responses and decision making. Finally, automatic recapitulation of patient outcome data facilitates monitoring and analysis, reduces human error and increases overall efficiency in radiology services. Thus, the web-based teleradiology application system optimizes quality, speed and accuracy in the flow of radiology services.

After implementation and testing, it was found that the role of this web-based teleradiology application not only reduced radiology image interpretation time, but also increased the accuracy of interpretation compared to previous methods which relied on sending images via email or instant messaging applications such as WhatsApp. The use of DICOM files in web-based teleradiology applications is key in maintaining image accuracy in sending radiology images, where in the process of sending images using WhatsApp or email the images are sent in jpg format which results in a decrease in image quality, and allows loss of information in the image.

5. Effectiveness of Web-Based Teleradiology Applications Compared to Previous Systems

Testing the effectiveness of a web-based teleradiology application system is an important step in evaluating its performance and usability in a practical environment. By providing a video of using the application and providing an application login link to respondents consisting of 20 radiographers, 20 radiology admins and 20 radiology doctors, this test aims to observe the extent to which this application can meet their needs in their daily work. In addition, providing a Google form (questions and attached results) filled in by the three groups of respondents also provides a more comprehensive picture of satisfaction and effectiveness of using the application in a real use context. By recording responses from each group, this test can identify the advantages and disadvantages of the web-based teleradiology application system compared to previous systems.

a. Radiology Admin Group Respondents

Respondents from the radiology admin group consisted of 20 admin people of various ages, and 45% of the respondents had work experience of more than 4 years and the rest ranged from 1 to 4 years. This admin group has experience using electronic media, namely WhatsApp, email and Telegram. The origin of the agencies from the radiology admin respondent group is 70% from private agencies and the remaining 30% from government agencies.

Tabel 4. 1 Tabel Respon Admin Radiologi

Ease of Features and Appearance		Ease of Use		Shorten the time		Automatic Feature	Report	Effectively Replaces Old Systems	
Easy	difficult	Easy	difficult	Yes	Just the same	Makes it easy	Just the same	Ye	No
20	0	20	0	19	1	20	0	20	0

The radiology admin response table above shows that all respondents stated that this application has features and is easy to use and also the automatic reporting feature makes performance easier and effectively replaces the old system, while for speed 19 people said it shortens time and 1 person said the same thing.

b. Radiographer Group Respondents

Respondents from the radiographer group consisted of 20 people and various ages, and 70% of the respondents had work experience of more than 4 years and the rest ranged from 1 to 4 years. This group of radiographers has experience using electronic media,

namely WhatsApp, email and Telegram. The origin of the agencies from the radiology admin respondent group was 55% from private agencies and 45% from government agencies.

Tabel 4. 2 Tabel Respon Radiografer

Ease of Features and Appearance		Ease of Use		Shorten the time			Effectively Replaces Old Systems	
Easy	difficult	Easy	difficult	Yes	Just same	the	Yes	No
20	0	20	0	18	2		20	0

The radiographer response table above shows that all respondents stated that this application had features and was easy to use and was effective in replacing the old system, while for speed, 18 people said it shortened time and 2 people had the same opinion. From the group of radiographers, one suggestion was obtained for downloading images if it could be done in a folder with certain criteria.

c. Respondents from the Radiology Doctor Group

Respondents from the radiology doctor group consisted of 20 doctors of various ages, and came from government agencies and private institutions. This group of radiology specialist doctors was specifically asked whether they usually used email to read X-ray images, and the results showed that 80% of respondents answered that they usually used email to read radiology images, while the other 20% answered that they did but not often.

Tabel 4. 3 Tabel Respon Dokter Radiologi

Easy to Understand and Use		Already Reading	Meets Needs	Image to be	Shorten the time		Effectively Replaces Old Systems		
Easy	difficult	Yes	Need to be completed		Yes	Just same	the	Yes	No
20	0	19	1		20	0		20	0

The radiology doctor's response table above shows that all respondents stated that this application has features that are easy to understand and easy to use and also the automatic report feature makes admin performance easier and effectively replaces the old system, while for speed 20 people said it shortens time. There were 19 respondents who stated that this application could replace email for readings, while 1 other person believed that it needed to be improved to sharpen and improve existing features so that

they better answer the needs of radiology practitioners. From the group of radiology doctors, 1 suggestion was obtained for this application.

Discussion

1. Design and Build a Web-Based Teleradiology Application System in Radiology Services

Teleradiology application testing includes all application pages accessed by admin users, radiologists and radiographers. The option to test entire application pages is critical because it ensures that every aspect of the teleradiology application has been thoroughly checked. From the login page which is the main gateway, to the detailed patient data page which contains vital information for diagnosis, this testing coverage allows the testing team to catch every possible error or defect that may occur at every stage of application use.(10)

The test results show that every function tested, starting from the process of adding and editing data to recording and recapitulating data, runs as expected and does not experience significant obstacles. This confirms that the application has passed a series of rigorous tests and meets established quality standards. Additionally, functional defect findings that may arise during testing can also be corrected quickly and efficiently, increasing the overall reliability and quality of the application.

The validity of the tested functions is strengthened by successful and thorough test results. These results indicate that the application has passed a comprehensive series of tests and is ready for use in a production environment. Thus, it can be concluded that thorough testing and valid results are important steps in ensuring that teleradiology applications can be relied upon in managing medical data and patient care in an effective and safe manner.

2. Contribution of Web-Based Teleradiology Systems in Speeding Up the Flow of Radiology Services.

The web-based teleradiology application system presents a significant transformation in the flow of radiology services, bringing changes to every stage of the process from data entry to delivery of results to patients. In the new radiology service flow, filling in patient data is carried out directly by the admin via the application platform, reducing the potential for errors and loss of information that might occur in manual filling. The steps for creating and sending DICOM images have been integrated in one system, ensuring speed and accuracy in data processing, and allowing radiologists to immediately access the images needed for analysis.

Image analysis by radiologists becomes more efficient with the web-based teleradiology application system, which provides direct access to images uploaded in DICOM

format. In addition, the availability of a structured results format helps radiologists in compiling interpretation results with better consistency and efficiency, speeding up the process of completing interpretations and sending results to parties who need them. With the option of sending via email or WhatsApp, interpretation results can be immediately conveyed to admin or patients without requiring a manual printing or sending process, optimizing time and resources.(11)

Improvements to the flow of radiology services also include increasing effectiveness through recapitulation of patient results data which is automatically compiled in the application system. With patient outcome data that is organized regularly and easily accessible, medical personnel can carry out monitoring and analysis more efficiently, as well as identify trends or patterns that may be important for further improvements in radiology services. In addition, integration with communication media such as email and WhatsApp allows faster and more efficient interaction between medical personnel and patients, increasing information accessibility and responsiveness in providing services.

By utilizing technology in the radiology service flow, the web-based teleradiology application system brings significant benefits to efficiency, accuracy and accessibility of information. The potential for errors and delays in the service process can be minimized, while the quality and speed in handling radiology cases can be improved. This not only provides benefits for medical personnel in improving the quality of services, but also increases patient satisfaction and trust in the radiology services provided. Thus, implementing a teleradiology application system is an important step in improving practice standards and patient experience in the field of radiology. (12)

3. Effectiveness of Web-Based Teleradiology Applications Compared to Previous Systems

Discussion of the effectiveness of web-based teleradiology application systems compared to legacy systems, such as the use of email, reflects a significant transformation in the way modern radiology operates. Data from respondents from various groups, including radiology admins, radiographers, and radiology doctors, shows a consensus in recognizing the superiority of web-based teleradiology applications. For example, positive responses from the radiology admin group highlighted the app's speed and ease of use, as well as the automated reporting features that made their work easier. Likewise, radiographers emphasized improvements in time efficiency and provided suggestions for more organized image downloading. In addition, radiology doctors appreciate the application features that make it

easier to read radiology images and replace the use of email, although there are several suggestions for improvements and improvements to the features to better suit the needs of radiology practitioners. (13)

Related research also corroborates the results of this test. Various studies have shown that implementing a web-based teleradiology application system can increase the efficiency of diagnosis and management of medical information, as well as increase collaboration between medical personnel. With easier and faster access to radiology images and patient data, practitioners can quickly make accurate diagnoses and provide appropriate treatment in less time. In addition, the integration of web technology also enables real-time exchange of medical information, which can reduce errors and improve coordination in patient care.(14)

Overall, the use of web-based teleradiology applications has had a significant positive impact in the field of health radiology. Compared to previous systems, such as the use of email, this application has proven to be more effective in optimizing diagnosis and medical information management. The positive response from various user groups, together with findings from related research, confirms that this move is a positive step in improving healthcare and accelerating patient access to quality care. Therefore, further investment in developing and improving the features of web-based teleradiology applications could be a smart step in improving the overall effectiveness of the health system.

Conclusion

Based on the results of research regarding the development of a web-based DICOM image teleradiology application in an effort to improve the quality of radiology services, the following conclusions were obtained:

1. The realization of a web-based teleradiology application that can display high resolution images, namely DICOM, and be implemented in the flow of radiology services.
2. Web-based teleradiology applications significantly improve the flow of radiology services by increasing efficiency, accuracy and speed in data entry, image analysis and delivery of results to patients
3. Web-based teleradiology applications have proven to be more effective than previous systems such as the use of email, by increasing the efficiency, speed and quality of medical information management in radiology practices.

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