Enterprise Medical Imaging: Design and Implementation of a Picture Archiving and Communication System for Effective Radiological Workflows

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Abstract

The goal of this study was to investigate the feasibility of designing and implementing a user-friendly and interoperable Picture Archiving and Communication System (PACS) that will be used for efficient and effective storage of medical images that are produced in public health facilities in Zambia. The introduction of a PACS platform is imperative as it could help curb the risks associated with storing medical images physically, some of the risks include loss of patient data, longer periods of retrieval of information in physical storage sites, theft, and unforeseen natural or man made disasters to mention but a few. Over the years,most hospitals and clinics have been using manual systems which are a slow, unreliable, costly, resource consuming and unsecured process of keeping and tracking medical images. Digital images are stored on optic discs and external harddrives; cassette films are stored in envelopes. Hence, one has to tirelessly search through to find specific details needed at a particular time. In an attempt to solve these problems, this study presents a PACS platform for the efficient and effective storage, management and access of digital medical image data which will be utilised by radiographers to send and store scanned images to radiologists who will use the said images to determine the state of the patient and refer them to a physician, when needed the information will be retrieved and distributed fast and easy between medical personnel. The system will act as storage storage and save on time of movements among other problems. The research carried out was both quantitative and qualitative. The study was carried out at the University Teaching Hospital (UTH) and the University of Zambia, in Lusaka and it was composed of radiologists, radiographers and IT personnel. Interviews were employed to collect data required to implement an interoperable Picture Archiving System.

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List of Abbreviations

Abbreviation	Description
AI	Artificial Intelligence
CXR	Chest X-Ray
DICOM	Digital Imaging and Communications in Medicine
EHRs	Electronic Health Records
EI	Enterprise Imaging
PACS	Picture Archiving and Communication System
RIS	Radiology Information System
UNZA	The University of Zambia
UTHs	University Teaching Hospitals

1. Introduction

Just like most third world countries, Zambia faces a number of challenges in all sectors of the economy especially the health sector. Zambia's progress in terms of efficient and effective medical delivery to the populace at large remains at a slow rate. The Medical Imaging sector has been plagued with lack of qualified radiologists, equipment and advanced technology. Currently, there are 9 radiologists working in public hospitals against a population of 18 million citizens and this ineptitude has amplified the need to make things better for the citizens .

Although recent years have seen the introduction of modern technology in the health sector, including some new medical imaging modalities, Zambia still lags behind. The non-systematic storage of images makes it hard to locate or access items when needed as compared to when they are stored digitally. Zulu and Phiri suggest the need to utilise technology to bridge the gap in radiological workflows by implementing Enterprise Medical Imaging (EMI) techniques which include storage and management, components of the Picture Archiving and Communication System, as part of a wider ecosystem of technologies that make up EMI strategies.

Zambia faces a critical shortage of trained radiologists, medical experts specialised in interpretation of medical images as result many imaging studies are sent offsite to be analysed due to a limitation of staffing. There's a dearth of radiologists globally and this puts pressure on the systems already strained by limited resources, ageing populations and complex funding challenges. This takes away from patient care and adds to delayed or wrong diagnosis as it leads to challenges in image access, retrieval, interpretation and sharing between medical personnel. Another major challenge is the lack of well-established digital storage systems in the health sector, this has compelled the radiographers to use the traditional ways of storing medical images using optic disks, X-ray films and paper files for image metadata and storage, however, this leaves the sector vulnerable in instances of unforeseen natural disasters such as fire, floods to mention but a few and other human posed problems like theft which might in turn affect effective service delivery in hospitals.

This project aims at investigating the feasibility of designing and implementing a user-friendly and interoperable Picture Archiving and Communication System (PACS) that will be used for efficient and effective storage of medical images that are produced in public health facilities in Zambia.

2. Related Work

2.1 Challenges with Radiological Workflows

2.1.1 Shortage of Qualified Personnel

Estimates indicate that two-thirds of the world's population lack adequate access to basic medical imaging services integral to universal health coverage and Zambia is not an exception.There is an overall lack of health resources in Zambia, for example, the number of doctors, nurses, and midwives per thousand population is only 0.982 while the WHO recommends a minimum of 4.45, Zambia faces a challenge of not having enough medical personnel for the radiology department countrywide and this slows down the process of delivering radiological findings to support medical diagnosis [1]. For this reason, most hospitals, especially in rural areas, have no radiological services,this leaves most diagnostic imaging examinations unreported [20]. This problem has been acknowledged in the National Health Strategic Plan of 2017-2021 as a hindrance to the provision of quality healthcare services and in ensuring universal health coverage in Zambia. The Radiological Society of Zambia (RSZ) is concerned about this challenge and discussions have been taking place within the radiography profession on how to extend the role of a radiographer to include image reporting. In addition, even this this small number of radiologists most of them are located in urban hospitals meaning Lusaka and the Copperbelt, leaving those in rural areas unable to access quality radiological services as they are in need of the services but can barely access them due to lack of personnel and healthcare facilities[10]

2.1.2 Need for Image Reporting by Radiographers in Zambia

There are some critical elements to every diagnostic imaging examination that the radiography sector in Zambia does not follow effectively. Firstly, the examination needs to be performed in a timely and accurate manner to maximise the diagnostic potential of the investigation[18]. Secondly, the report on the findings of the examination must be timely and effectively communicated to the referring medical practitioner to ensure it serves its purpose in the patient's treatment pathway. In addition to critical elements outlined, most of these images are carried by patients for convenience. However, this poses a threat as there might be loss of images and other related information [2].

2.1.3 Out of service Equipment and Lack of Softwares

Medical imaging equipment are an important component of the health system and are tools used in radiology to prevent, diagnose, monitor and treat diseases as well as during rehabilitation after disease or injury. It can be in the form of a machine, instrument, appliance, software or material intended by the manufacturer to be used alone or in combination with other devices. Medical equipment have a life cycle requiring calibration, maintenance, repair, user training and finally retirement[18]. A responsive health system guarantees communities equitable access to essential medical equipment of assured quality, safety and cost effectiveness. Shortage of medical equipment, either due to unavailability or non-functioning, is a barrier to the ability of the health system to deliver quality health

services[11]. The World Health Organization estimates that between 50 to 80 percent of medical equipment in developing countries is not functioning and those countries lack technology assessment systems and regulatory controls to prevent importation of inferior medical equipment. These make the countries exposed to dishonest market practices that put patient's lives at risk. Zambian health care facilities that handle medical images lack an electronic and interoperable system[21]. There is no interoperable system that can be used for effective management of data. This has led to workers being overworked, Zambia has made efforts to strengthen imaging services, these services have not been improved. There is also a lack of routine servicing, further the supply chain management system for imaging consumables is weak, this has led to occasional inappropriate procurement and frequent stock outages of specialised imaging supplies [13]

2.1.4 Storage Challenges

A survey shows that most developing countries use the traditional way of storing medical images as compared to the modern trends. Most of the images are stored on physical storage mediums such as optic disks and paper files. This is due to the lack of well established online storage systems. Moreover, technological facilities are expensive to implement, maintain and upgrades or changes to the system come with risks and inconvenience to the users who might be forced off the system during maintenance. In addition, most of the technologies require constant power supply, wi-fi/internet to run effectively, meaning if these are absent then it will be hard to access these facilities' storage facilities [10].

2.2 Free and Open Source PACS Platforms

2.2.1 Whole-Side Imaging Systems in Pathology

The whole-slide imaging systems (WSI) are automated digital microscopic systems that capture digital images of the physical slide and create a virtual slide. The virtual slide can then be shared and be reviewed by multiple health practitioners as it enables both collaborative and remote review. However, the WSI systems produce very large images with several gigabytes that require viewer applications with special functionality to fulfil the pathologist's need and this is just one of the numerous barriers that have been slowing down this process, including performance issues, workflow efficiency, infrastructure, and integration with other software which consequently affects smooth collaboration between these health professionals [17].

2.2.2 Orthanc Open-Source DICOM Server

Orthanc is an open-source standalone Digital Imaging Communications Management (DICOM) server that aims at providing easy implementation with ease of installation, configuration, running and integration. Orthanc is used in many medical facilities around the world as well as integrated with some medical solutions and startups aiming to provide professional medical imaging services.The Orthanc server can be extended with plugins that provide solutions for teleradiology, digital pathology, or enterprise-ready databases. Software developers and research engineers can easily develop external software or Web portals

dealing with medical images, with minimal knowledge of the DICOM standard, thanks to the advanced programming interface of the Orthanc server [23]. It is designed to improve the DICOM flows in hospitals and to support research about the automated analysis of medical images. Orthanc lets its users focus on the content of the DICOM files, hiding the complexity of the DICOM format and of the DICOM protocol[22]. An interesting distinction that exists between Orthanc and some of the similar systems is the fact that it provides a RESTful API. Thanks to this major feature, it is possible to operate Orthanc from any computer language. The DICOM tags of the stored medical images can be downloaded in the JSON file format. Furthermore, standard PNG images can be generated on the spot from the DICOM instances by Orthanc. It also features a plugin mechanism to add new modules that extends the core capabilities of its REST API [8].

2.2.3 MRIdb: Medical Imaging Database

MRIdb is a self contained image database, particularly suited to the storage and management of magnetic resonance imaging data sets for population phenotyping. It integrates a mature image archival system with an intuitive web-based user interface that provides visualisation and export functionality [14]. In addition, utilities for auditing, data migration and system monitoring are included in a virtual machine image that is easily deployed with minimal configuration [4]. However, MRIdb uses the DCM4CHEE archive (that doesn't do much in a stand-alone situation) and PostgreSQL which when compared on performance metrics to some alternatives that may be suitable for use in such systems, is slower .

2.2.4 Dicoogle

Dicoogle is an open source Picture Archiving and Communications System (PACS) archive. Its modular architecture allows the quick development of new functionalities, due the availability of a Software Development Kit (SDK) [9].

It is an extensible, platform-independent PACS archive software that replaces the traditional, usually hard-coded centralised database with pluggable indexing and retrieval mechanisms, which are developed separately and installed in deployment time. It was initially designed to accommodate automatic information extraction, indexing and storage of all meta-data detected in medical images, without re-engineering or reconfiguration requirements, thus overcoming the limitations of DICOM-compliant query services [5].

Currently, the extensible architecture of Dicoogle has enabled its use in research and the healthcare industry, by covering a wide variety of use cases without changes to the core system. This is very relevant nowadays, given the need to improve, monitor and measure the efficiency of medical imaging systems, as well as to extract knowledge from the produced medical images, including healthcare quality indicators. As such, Dicoogle can be used as a base platform for DICOM data mining [9].

Dicoogle provides a few plugins that come bundled with the system such as the Lucene Index/Query Plugin and the File Storage Plugin. The Lucene plugin is based on Apache Lucene to support indexing and querying of DICOM meta-data. With this plugin set, it is

possible to index nearly all meta-data and perform free text, keyword-based, and range-based queries. Indexing a directory is done simply by accessing the Indexer page, on the side bar. In this page, one can select a root directory to index. The path is a URI defined according to the storage provider, and defaults to the file scheme.

The search page enables users to execute queries over the indexed meta-data and in the search interface, it is also possible to select which providers to query. Query providers are actually Query Plugins, that are installed either in the local instance of Dicoogle, or in remote instances if the platform is using the WAN plugin. Therefore, users of the system are urged to be careful and select exactly which providers they want to query, in order to retrieve more accurate and faster results.

After running a query, the result browser shows up, giving the user an intuitive hierarchical view of the results. On this page, there is also an Export button, which is used in order to export the query results into a CSV file. When the export button is clicked, the user has to select which tags (s)he wants to export in the CSV file. This selection is heavily assisted by the interface, on which the user may type an incomplete tag and have presented the available candidates that match the inserted term. Moreover, the text box allows users to copy a list of tags directly from another CSV file, enabling an easier generation of reports.

On the other hand, the file storage plugin is used for the storage of DICOM Files. This plugin is necessary in order to use Dicoogle as a complete DICOM Storage Provider. The core platform provides a fallback implementation which supports reading (but not storing) files from the local file system. For storage purposes, the file storage plugin maps the DICOM hierarchical organisation (Patient->Study->Series->Image) into a directory tree in the file system. Every object in the Dicoogle Platform may be traced back to its storage location by a URI, similar to file:/tmp/file. In order to support multiple providers, every Storage plugin defines a unique scheme, which maps to the protocol used to store and retrieve content.

2.3 Design and Implementation of Medical Imaging Platforms

2.3.1 Cybersecurity

Most healthcare systems are in the cross hairs of cyber attackers as components are integrated in a central system. The attacks include virus infections, ransomware, theft, or publication of patient data and many more. Recent years have seen a dramatic increase in the healthcare cyber attacks worldwide especially in medical imaging and PACS systems, hence, the need to implement various security measures. The following are some recommended measures to implement when setting up a PACS platform, one is employing physical security, making sure that cable networks ports are in supervised areas,. The second measure involves configuration of the network plugs to accept connections only from known addresses by defining a secure wireless network configuration, review and update plan and splitting the network into different segments, with firewalls in between. Another measure is ensuring the operating system and application softwares updated as regularly as possible, install anti virus

software where permitted, configure operating system to only permit whitelisted applications and use a network monitoring or intrusion detection system and perform regular backups. DICOM/HL7 also has specific measures to ensure there is cyber security, and these are, use fixed installation of DICOM viewer for media import for media import, protect DICOM and HL7 network connections with transport layer security. Additionally, use DICOM user identity information to restrict access to the PACS and when importing DICOM files always clear the so-called file preamble. Furthermore, validate encapsulated documents or compressed images before display or put the compressed images in a sandbox process, protect DICOM images and documents with digital signatures and use application logic to block suspicious HL7 update/merge operations or just verify digital signatures when reading DICOM image or documents [6].

2.3.2 Storage

The architecture and design structure of a PACS database is critical for the efficient access and integration of PACS operations. Designing storage requires careful understanding of the data and processing needs of radiologists, referring physicians, radiology staff, administrators, and researchers. Due to access requirements. The PACS system makes use of databases for storage of medical images and associated information instead of physical storage like film, CD and DVDs [19]. The databases will make it possible for information to be accessible and shared by different departments which might have different uses for it. There will be explicit support for integration of any digital object type, metadata or new service that will be done under the Dicom protocols. The centralised database server will enable the PACS to cut down on data redundancy and inconsistency while still maintaining fast user response for text and image data queries.

2.3.3 Imaging Formats (DICOM standard)

When it comes to medical imaging, there are a lot of image formatting types that exist and each of them come with their own characteristics that affect the storage and accessibility of medical images when using the PACS system. From the vast number of image format types, the digital imaging and communications in medicine (DICOM) stands out to be the most efficient and recommended for PACS systems in medicine. DICOM is used worldwide to store, exchange, and transmit medical images and has been central to the development of modern radiological imaging. It incorporates standards for imaging modalities such as radiography, ultrasonography, computed tomography (CT), magnetic resonance imaging (MRI), and radiation therapy [12]. The two main components of DICOM are the DICOM file format and the DICOM network protocol. These two components work together to make sure that images are in a standardised format and the exchange of images is also standardised. The DICOM files contain more than just images. Every DICOM file holds patient information such as names, ID, sex and date of birth and all medical imaging applications that are connected to the hospital network use DICOM protocol to exchange information. The DICOM network protocol is used to search for imaging studies in the archive and retrieve imaging studies to the workstation in order to display it [7]. There are also advanced network

commands that are used to schedule procedures, report statuses and share the workload between doctors and imaging machines.

2.3.4 Large Images in Digital Libraries

It is common for digital archives and collections to have high resolution images that have been captured in a lossless format in order to preserve as much detail as possible. This is important for ensuring data collected is of high quality and no important details are missing. The large sizes of images raises problems when it comes to sharing and viewing of these images as some typical computer screens are only able to display a fraction of the resolutions of large image files, thus forcing solutions such as scaling, which results in loss of detail [15]. There are a number of approaches to supporting large images with the most common approach being the use of Zooming User Interfaces (ZUIs), a graphical environment where users can change the scale of the viewed area in order to see more detail or less, and browse through different documents [15]. An example of a popular ZUI interface is Google Maps and one of the few tools that provides large image support in a digital library is Atmire's Image Zoom Module2 which processes large images, stored in a repository, for fast and user friendly visualisation in the browser. Another example of a large image support tool is Zoomify Image, a tool that allows you to create interactive, zoomable images from large image files and display them via a content management system.

2.3.5 Enterprise Medical Imaging (EMI)

Enterprise Medical Imaging (EMI) is a set of strategies, initiatives and workflows implemented across the healthcare enterprise to consistently and optimally capture, index, manage, store, distribute, view, exchange, analyse all clinical imaging and multimedia content to enhance the electronic health records. It involves the storing of DICOM images from the traditional imaging modalities commonly referred to as the Medical Image Management System (MIMPS) to a better technology known as Vendor Neutral Archive (VNA). This research focuses on the PACS workflow which is an aspect of the EMI, it automates complex imaging workflows such as delivery of images from remote locations, the radiographers capture and integrate visible light images, videos with corresponding patient health records and these are sent to a PACS for viewing and storage by other medical personnel such the radiologists/physicians. In addition, EMI provides cognitive intelligence using built in analytics engines that extract crucial health information and identifies high risk patients. These EMI platforms lessen storage costs and offer tools for information life cycle management while offering business continuity solutions and disaster recovery options in case of unforeseen events [23].

2.3.6 Hospital Management Systems

A Hospital Management System (HMS) is a system enabling hospitals to manage information and data related to all aspects of healthcare processes, providers, patients, and more, which in turn ensures that processes are completed swiftly and effectively. When one thinks of the

various aspects and departments of a hospital, it becomes apparent that an HMS is critical. The hospital database management system was introduced in 1960, and has greatly evolved since then, with the ability to integrate with the existing facilities, technologies, software, and systems of a hospital. Today, patients can begin the process of healthcare in the palm of their hand through the use of mobile devices and apps. This process then moves to the healthcare providers and hospitals.

For the hospitals, HMS translates to being able to track patient history, provide better care, keep track of appointments, save patient insurance and payment data, enable doctors and clinicians to check patient history, maintain patient care continuity, and save time and effort on unnecessary tedious manual tasks. This Electronic Medical Record (EMR) or Electronic Health Record (EHR) is the journey of a patient with the hospital – keeping track of the date of every visit, doctor consulted, medicines and advice prescribed, and other information for the patient. This ensures that even if a patient visits after a long break, the patient and hospital will not require going through the registration process again.

The picture archiving and communication system needs to be interoperable with the HMS of the institution at which it is being used to ensure easy interchange and access of digital radiological images and associated case reports to make it easy for health practitioners to keep track of overall patient information, disease background and progression that would help in coming up with well informed treatment plans at a faster and more convenient rate.

Some of the key features of a Hospital Management System include operation theatre management, patient, facility and report management and security. When it comes to radiology related surgeries, chemotherapy or other treatment procedures, the processes are long and tedious and a hospital must know the schedule of these procedures, to avoid overbooking and ensure availability of the required surgeons, other doctors and operation theatre staff. A hospital would be able to send operation schedules, test results, and other details to patients/next of kin, while also sending reminders to the presiding surgeon and other staff required for a procedure.

With faster, secure, and easy data retrieval, a hospital/healthcare facility would be able to provide better and efficient care to the patients. With every department interconnected and integrated into the HMS, the quality of patient care can be enhanced, leading to greater customer satisfaction and lowered turnovers. Hence, the PACS stands to benefit massively from the interconnection it would have with the HMS which in turn would help improve the entire radiological workflow. Today there is severe competition even in the realm of healthcare, and patients and their kin prefer to visit a facility that is efficient, cost-effective, and secure.

A comprehensive Hospital Management System will enable the addition of several branches across locations of the hospital. This ensures that patients can visit any branch for treatment and the doctors would be able to access their records from anywhere and this includes branches such as the radiology department. The HMS enables your health facility to care for

its patients better through faster processes, storing and analysis of patient history, preparation and access of real time reports, appointment scheduling and tracking, and many more such processes. Employees, too, find it easier to manage the huge numbers of patients, records, and other jobs critical to the smooth functioning of a healthcare facility.

The cloud-based medical records software in a Hospital Management System, ensures that all data remains interlinked and with high security. This translates to ease of data storage and retrieval by authorised personnel only. Faster access to accurate data has a significant impact on the speed and efficiency of the overall operational and administrative processes of a hospital/healthcare facility that would also benefit the radiology department as well as the entire health institution.

3. Methodology

3.1 Current Storage, Management and Accessibility of Medical Images

This chapter describes the research design, target population, sample population, research instruments and data collection procedures and data analysis. It outlines and describes research methods and techniques that were used in conducting this research. It will start by explaining the area of study, research design and data collection instruments. Population and sample size and technique considered in this study will be explained as well. The methods of data collection, data analysis tools which were used to analyse data are explained, limitations encountered during the study, issue of data validity and reliability as well as ethical consideration will be covered.

3.1.1 Research design and approach

Research design is a basic plan that guides data collection and analysis in a study and it has to have a plan with a set of rules that enable the researcher to conceptualise and observe the problem understudy.

In this study the researchers applied the qualitative research method that involved collecting and analysing non-numerical data to understand concepts, opinions or experiences of the stakeholders involved as well as gather in-depth insights into the research problem. The qualitative approach helped to study attitudes, opinions, behaviours, and other defined variables of the population.

3.1.2 Sample population

A sample population can be defined as a group or subset of the total populations selected for observation and analysis. The target population included radiologists, radiographers and IT personnels at University Teaching Hospital and Levy Mwanawasa General Hospital.

3.1.3 Study Setting

The study was carried out at the University Teaching Hospital (UTH). The target population included radiographers and radiologists at UTH. Snowball sampling procedure was used together with conducive sampling for selection of participants.

3.1.4 Sampling procedures

The study used two types of sampling procedures which are snowball and conducive sampling methods. Snowball sampling or chain-referral sampling is defined as a non-probability sampling technique in which the samples have traits that are rare to find. This is a sampling technique, in which existing subjects provide referrals to recruit sample units required for a research study while purposive sampling means that respondents are chosen on the basis of their knowledge of the information desired. Both Snowball and purposive sampling were used in choosing radiologists and radiographers as they were concerned with the improvement of the radiological workflow, specifically, the digitalization of the storage of radiological images. Through these sampling processes a total of 7 participants which included 2 radiologists and 5 radiographers were chosen.

3.1.5 Data collection instruments

The research used interviews to collect required data from the study population. This study employed structured interviews which are a systematic approach to interviewing where all candidates were asked the same predetermined questions in the same order. Structured interviews can be conducted face to face, online or over the telephone, sometimes with the aid of lap-top computers. But in this study, the interviews were conducted face to face with a standard duration of less than 20 minutes on each session. Other instruments included audio recorders on smartphones and notepads that were used to collect data and notes from the interview sessions.

3.1.6 Validity and reliability of the study instruments

To establish validity of the instruments applied, the researchers conducted a pilot study prior to the actual data collection. The instruments were tested by providing it to group members. The instruments were presented to the supervisor for further comments and improvement hence all necessary adjustments were made for items which were found unsuitable were removed. To ensure reliability of the collected information, some of the items during the interviews were asked more than one time to the respondents to see if there is consistency in responses from the respondents.

3.1.7 Data analysis procedures

Data analysis is a process of editing, coding, classification and tabulation of collected data. The process involves operations which are performed with the purpose of summarising and organising the collected data from the field. Since the study was qualitative, the data obtained using interviews was analysed by considering major themes to extract relevant information. This helped the researchers to make a description of the data collected from the field based on research objectives and derived conclusions on what to take regarding its usefulness.

3.1.8 Ethical consideration

The researchers sought ethical clearance from the University of Zambia Biomedical Research Ethics Committee (UNZABREC) with ethical clearance approval code: (REF. NO.

2731-2022), National Health Research Authority (NRHA) under Ref No: NRHA000024/10/05/2022 and approval was granted by the University Teaching Hospital and Levy Mwanawasa University Teaching Hospital to conduct studies at the two facilities. The researchers obtained informed consent from the research participants and stakeholders, Participants were guaranteed the confidentiality of the research findings and their identity. The researchers ensured the freedom of participants by adhering to the principle of informed consent. This principle required the researcher to ensure that participants were aware of the purpose of the study so as to get their concern and participate freely. The statement of the research purpose, description of any potential risks or discomforts, description of potential benefits and the description of confidentiality were assured to the respondents. These findings were stored in such a way that they will be accessible only for the research purpose so as to maintain privacy or confidentiality of the respondents, data was stored on a shared google drive restricted to only the researchers.

3.2 Design and Implementing an Interoperable PACS Platform

This section defines the design structure and implementation of the project software. It specifies the architectural design of the software, taking into accounts its structure, components and the relationship and interaction between its components. The context diagram below shows how the system in its working environment:

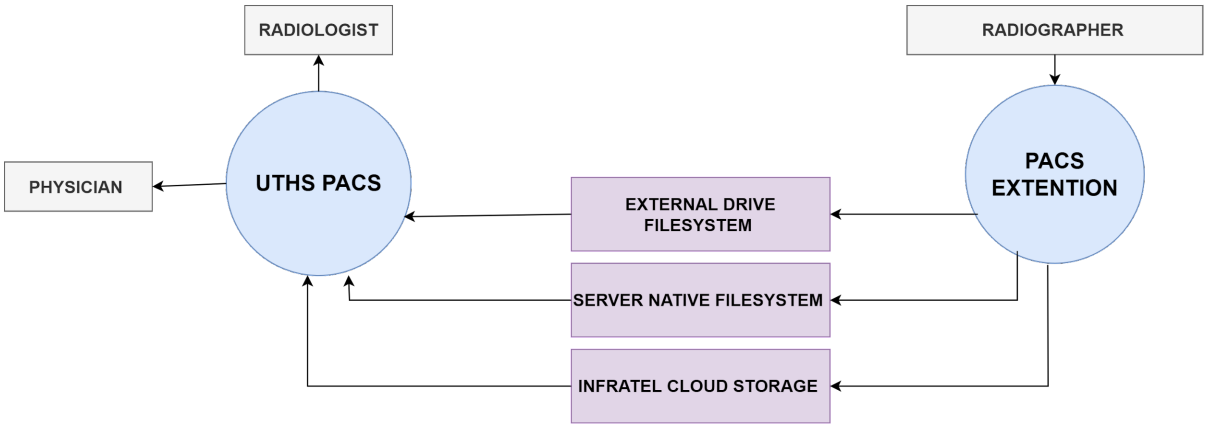

Figure 2.1: Context diagram

3.2.1 Architectural design

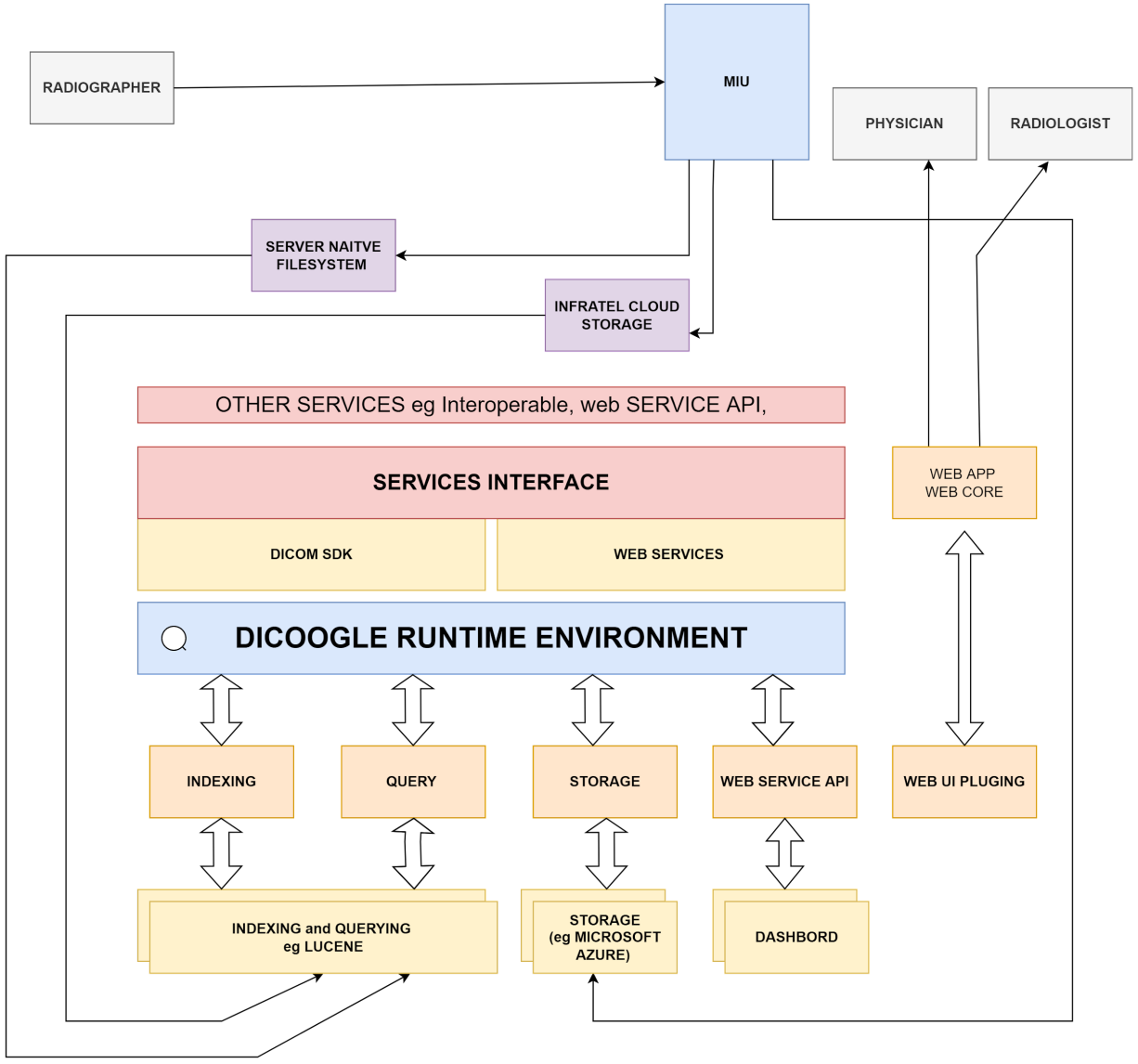

Figure 2.2: Block diagram

The UTHs PACS platform is a web based application that was implemented using the integration and configuration process model which is based on reuse of existing software. Hence the UTHs PACS platform was implemented by customising already existing software (Dicoogle PACS) to suit the specific requirements that were elicited from the stakeholders. Since the PACS does not have a feature for directly adding medical images into the system, a third party software for uploading images into the PACS was developed. The third party system which is known as the Medical Image Uploader, is a web based application that is capable of uploading images into the storage folder of the PACS as well as pushing images to a designated cloud storage account for remote storage and these images can be indexed from the PACS to make them accessible to the user.

3.2.2 Interface Design

The PACS platform is hosted on a web service with a graphical user interface that includes elements such as a search field, indexer pages where manual indexing of images is done and a management panel that has different admin functionalities such as indexing options, transfer options, services and plugins and storage server. The web platform will enable the user to interact with the PACS on any operating system. The Medical Image Uploader's user interface includes elements such as the image uploading panel, a metadata verification page where the user can verify the metadata associated with the image before an upload is confirmed and optional to upload an images to either a storage folder on a local machine or to a cloud storage.

3.3 Evaluating the Usefulness and Effectiveness of PACS Platform

3.3.1 Sample population

The target population for the evaluation of the UTHs PACS included radiologists in training at the University Teaching Hospital. There were a total of 10 participants that took part in the study.

3.3.2 Study Setting

The study was carried out at the University Teaching Hospital (UTH) in Lusaka for eight of the ten participants that were interacted with physically. The other two participants were sent instructions through email.

3.3.3 Sampling procedures

The study used two types of sampling procedures which are snowball and conducive sampling methods. Snowball sampling was used in choosing the participants.

3.3.4 Data collection instruments

The evaluation process used a questionnaire to collect required data from the study population. This study employed a TAM questionnaire which was provided online for users to fill in after interacting with the system. Other instruments included smartphones and computers for the purpose of performing the tasks.

3.3.5 Validity and reliability of the study instruments

To establish validity of the instruments applied, the researchers conducted a pilot study prior to the actual data collection. The instruments were presented to a radiologist, the team supervisor, for testing, further comments and improvement hence all necessary adjustments were made for items which were found unsuitable were removed.

3.3.6 Data analysis procedures

The process involves operations which were performed with the purpose of summarising and organising the collected data from the field. The analysis process for the data collected through the questionnaire was done using SPSS (Statistical Package for the Social Sciences).

3.3.7 Ethical consideration

As it was with the requirements elicitation process, the study utilised the already sought ethical clearance from the University of Zambia Biomedical Research Ethics Committee (UNZABREC) ethical clearance approval code: (REF. NO. 2731-2022), National Health Research Authority (NHRA) under Ref No: NRHA000024/10/05/2022 and approval was granted by the University Teaching Hospital to conduct a study at the institution. Lastly, participants were required to consent to the study before the test was conducted and their confidentiality was guaranteed.

4. Results and Evaluation

4.1 Evaluation

Evaluation and testing is a major step in the development of the PACS platform. It is a vital phase in quality assurance of the system in terms of assessing the system quality and sophistication from diverse viewpoints. There are a number of methods and questionnaires that are used for evaluating or assessing usability of the technological products based upon the user perception and these include tools such as the Questionnaire for User Interaction and Satisfaction (QUIS) , the Software Usability Measurement Inventory (SUMI), the Computer System Usability Questionnaire (CSUQ) and the Technology Acceptance Model (TAM) questionnaire.

The evaluation process of the PACS made use of the TAM questionnaire version 2 generally known as the TAM2 questionnaire which is an improvement over the original TAM questionnaire [3]. TAM determines the user's level of acceptance of the technology by evaluating perceived usefulness, perceived ease of use, job relevance and output quality among other things. In this light, perceived usefulness reflects the extent to which an individual believes a system could enhance task performance. Therefore, the TAM questionnaire was chosen for the evaluation of the usefulness and by extension, the effectiveness of the UTHs PACS.

4.1.1 Study design

In the testing session phase, the group designed and executed the test cases for the system. The first objective was to measure the usefulness and effectiveness of the PACS platform. At the start of the session, participants were briefed about the study and subsequently required to sign a consent form to show that they understand and agree to take part in the study. For each session, the users were introduced to the objective of the experiment and were given the guidelines on how to conduct the experiment. All participants were provided with an instruction manual that contained a specific set of tasks that all users were required to carry out while the group monitored and provided further guidance where the users were in need of it. All users were required to perform the series of predefined tasks shown in Table 2.1 below:

Table 4.1: study tasks

INPUTS	● Website URL: **netd.ac.zm:8081** ● Login details: (username = **uthpacs**, password = **uth**) ● Patient Full Name ● Patient Last Name ● Patient ID
ASSUMPTIONS	
STEPS	1. Insert website URL "**netd.ac.zm:8081**" in address bar 2. Login into PACS platform using username "**uthpacs**" and password "**uth**" 3. Go to the search bar and search an image by: a. Patient Full Name: **Shankalu Lazarous** b. Patient Last Name: **Shankalu** c. Patient ID: **US222**
EXPECTED DURATION	4 minutes

After the completion of all tasks, the users were required to fill in the questionnaire based on their interaction with the PACS platform.

4.2 Results

4.2.1 Current Storage, Management and Accessibility of Medical Images

4.2.1.1 Introduction

This section presents the findings of the interviews that were carried out at the University Teaching Hospital and Levy Mwanawasa Teaching Hospital where registered and practising Radiologists and Radiographers were interviewed . Seven willing participants agreed to be interviewed and provide the research team with the needed information aiding the project about how medical images are currently being stored and accessed across the medical fraternity, furthermore, the participants also gave their comments on various issues affecting the radiological workflows , how they can be improved and recommended some features that would be added to the App in development by the research team to make their work easier and better. The findings were based on the research questions in the table below

Table 4.2:Shows interviewees Demographics

NAME	AGE RANGE	EXPERIENCE	UTHs	LMUTHs
Radiographer 1	25-35	Over 5 years	✔	
Radiographer 2	25-35	Over 5 years	✔	
Radiographer 3	25-35	Over 6 years	✔	
Radiographer 4	25-35	7 years	✔	
Radiologist 1	25-35	Over 7 years		✔
Radiologist 2	25-35	Over 5 years	✔	

4.2.1.2 State/format of storing radiological images and storage of radiological images

The current storage of images is done using CDs, radiographs and hard-drives or flash disks. The radiographs or films are stored in store rooms, softcopy images are stored on external hard-drives and because of low storage capacity, some images go back with the patient. On this point, radiographer 1 in their interview commented that they do not mostly remain with copies especially for x-rays when they are given to the patients and in an instance that the patient loses the x-ray they might need to get another one done. Furthermore, Radiographer 2 highlighted the fact that since the images are retrieved based on the patients requests, it is hoped that they do not request since the facility might not even have a copy. During the interview, radiographer 3 also highlighted the fact that the existing systems have no enough space to store the huge amounts of data generated making the systems unreliable. Adding radiographer 4, commented that accessing images is hard as they're a lot of files to check through in store rooms as they are not well sorted making difficult to retrieve vital files when needed.

4.2.1.3 Retrieval of radiological images and Required image storage period

This is done by going through the stored images in the store rooms and searching for patient name/record ID or using any metadata available even on existing PACS or digital medical systems. Radiologist 1, made mention of a 5 years departmental policy within the University Teaching Hospitals that regulates how long an image is stored and when it can be discarded. However, the participant added that images should not be discarded for the purpose of further study or research just like the one being carried out by the researchers and legal matters that may arise at the hospital. Radiologist 2 added to say, “since the storage rooms run out , the hospitals discard the images and give the films to recyclers that extract the silver from the film (silver recovery).”

4.2.1.4 User recommended features

This section takes into account the suggested solutions and features collected from all the participants for the development of a PACS system. Radiographer 1,2,3 and 4 all suggested that the system should be interlinked with existing medical systems within the hospital as well as systems from other medical institutions both locally and countrywide. Radiographer 3 also suggested that the storage capacity should be improved by handling huge amounts of data and users should be able to have access to the platform from anywhere in a ubiquitous manner. Radiologist 1 recommended that the system should be interoperable with other hospital management systems. Radiographer 2 added that the system users should be able to navigate through the system and browse for images using the image meta-data such as modality,patient name, patient ID and many more. Both radiologist 1 and 2 suggested that the cloud hosting service should be able to store/keep images until the user decides to discard them and the system should be able to store digital images both on the machine and the cloud storage.

- The system should be interoperable with other hospital management systems
- The system should hold huge amounts of data
- Users should be able to retrieve and access data in a ubiquitous manner
- Users should be able to navigate through the system and browse for images using the image meta-data such as modality,patient name, patient ID and many more.
- The cloud hosting service should be able to store/keep images until the user decides to discard them
- The system should be able to store digital images both on the machine and the cloud storage.

4.2.1.5 Summary

This section presented findings on the current storage of images and how they are retrieved/accessed at the University Teaching Hospitals in Zambia by radiologists and radiographers. The study also revealed that access and retrieval of the medical images is hard and highlighted the need to make the situation better. It also brought out the various modalities and formats stored in different mediums such CDs, films, offline store rooms and many more. The study also recommended some features to be attributed to the system to make the radiological workflow easy and faster than the traditional ways of doing things. They also showed that the University teaching hospitals are implementing a parallel changeover where old traditional systems and new technological based systems work hand in hand in the service delivery. The chapter also projected the feasibility of designing and implementing a user-friendly and interoperable Picture Archiving and Communication System (PACS) that will be used for efficient and effective storage of medical images that are produced in public health facilities in Zambia.

4.2.2 Design and Implementing an Interoperable PACS Platform

4.2.2.1 UTHs PACS Login

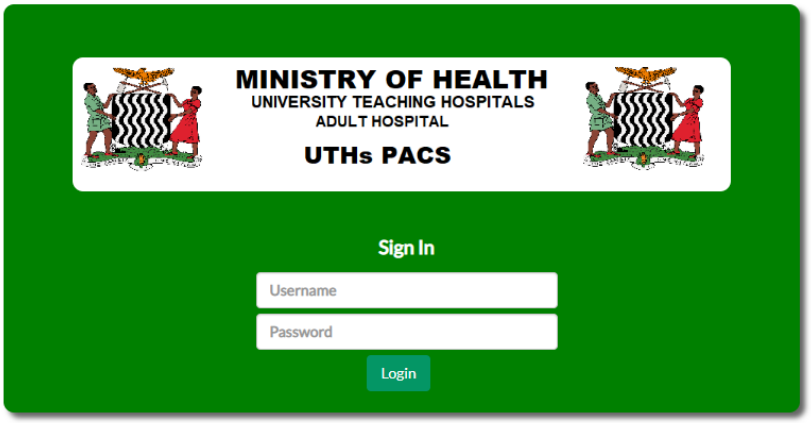

Figure 4.1: Login page

Figure 4.1 Shows the Login page for the UTHs Picture Archiving and Communication System. The users of the PACS platform shall be able to login to the system in order for them to carry out their tasks. When the user visits the system's webpage, they will be presented with the login page where they will be required to enter their credentials and click the "login" button. The system shall then redirect them to the home/search page of the PACS platform. For the user to login to the PACS platform, they shall have to provide a valid username and password. If the user provides the correct credentials, they shall be able to login but if the credentials provided are invalid, then login access to the system will be denied.

4.2.2.2 UTHs PACS Search

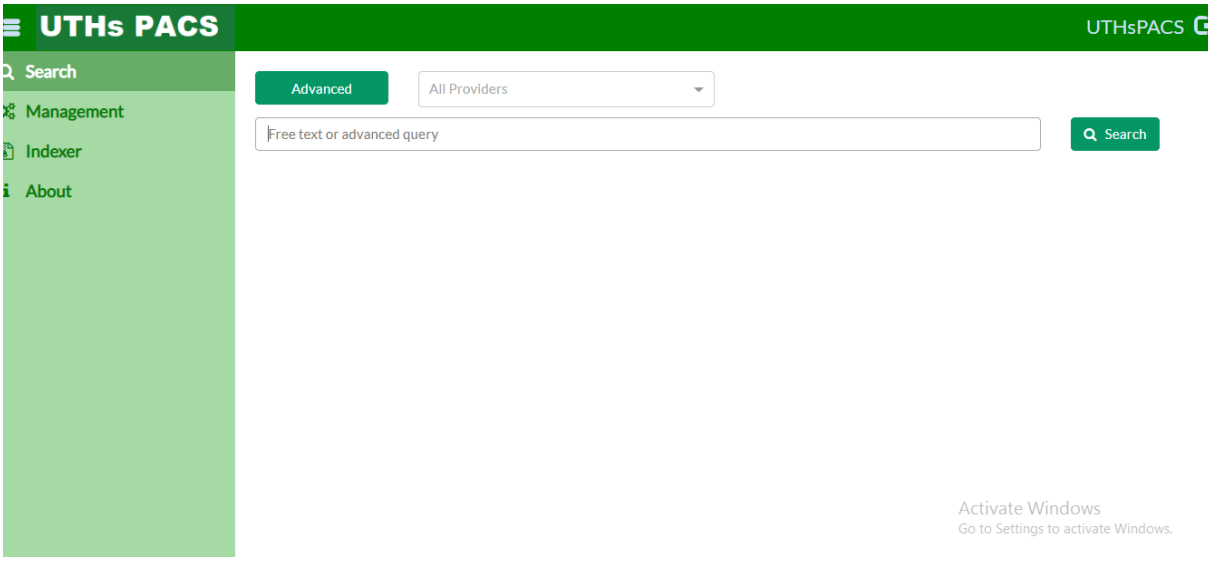

Figure 4.2: Search page

Figure 4.2 Shows the Search page for the UTHs Picture Archiving and Communication System. The users of the UTHs PACS shall be able to search for DICOM standard images in the search field using a string that represents what the user wishes to fetch from this source. In order for information to be properly retrieved by the web application, the search should follow the classic Lucene query parser syntax [16].

4.2.2.3 UTHs PACS Result Page

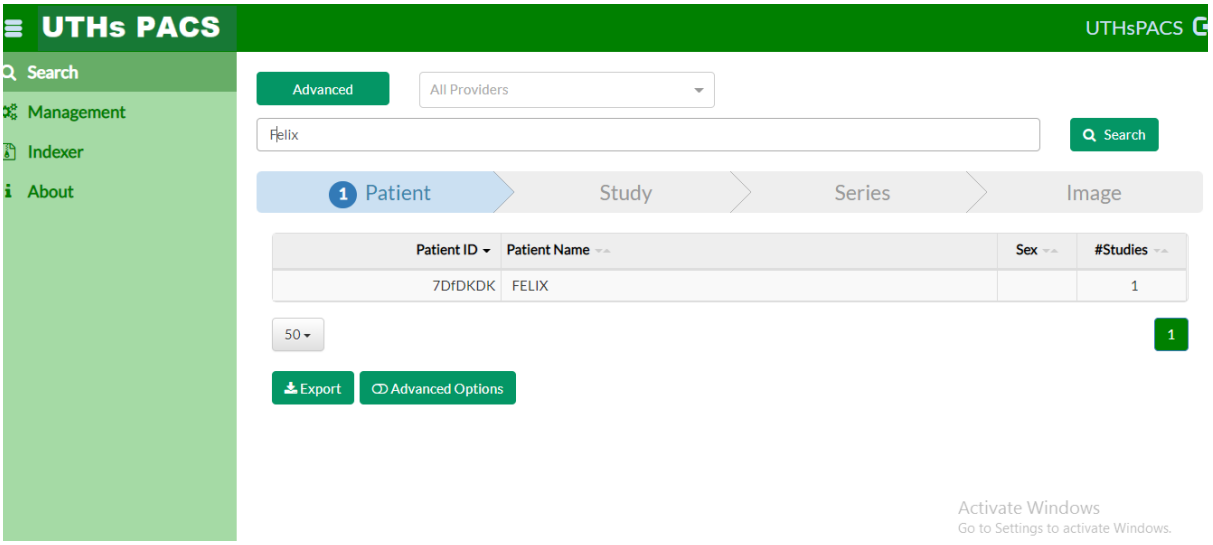

Figure 4.3 Results page

Figure 4.3 Shows the results of a query madepage in the Picture Archiving and Communication System. The user can view information associated with the patient, the study, the series and the image itself.

4.2.2.4 UTHs PACS Metadata Review

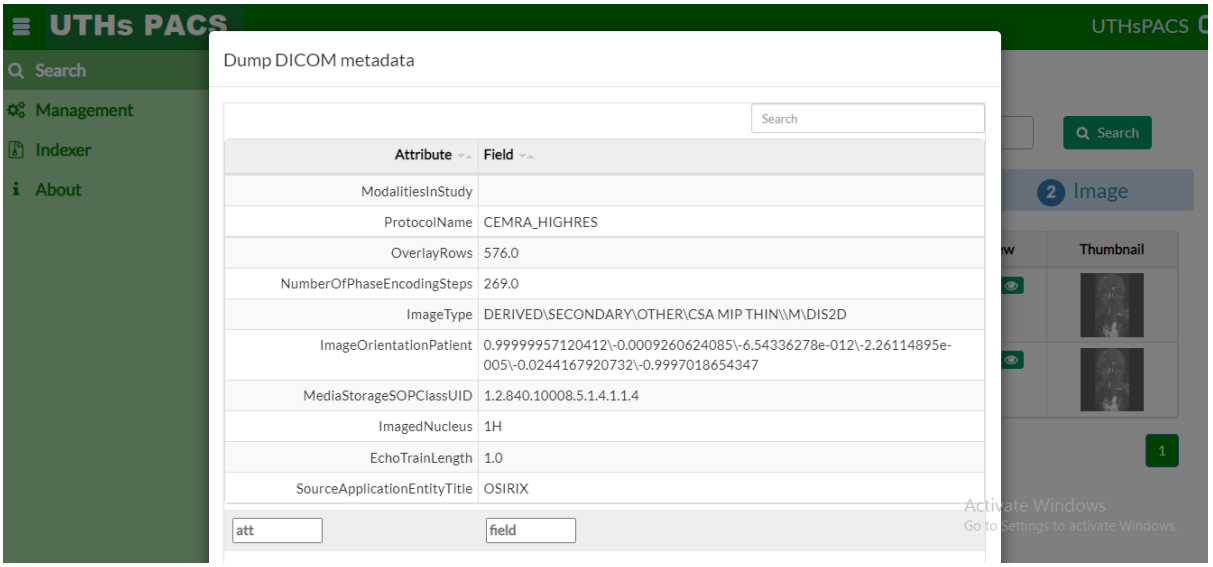

Figure 4.4: Metadata review page

Figure 4.4 Shows the Metadata Review page for the UTHs Picture Archiving and Communication System.

4.2.2.5 UTHs PACS Export

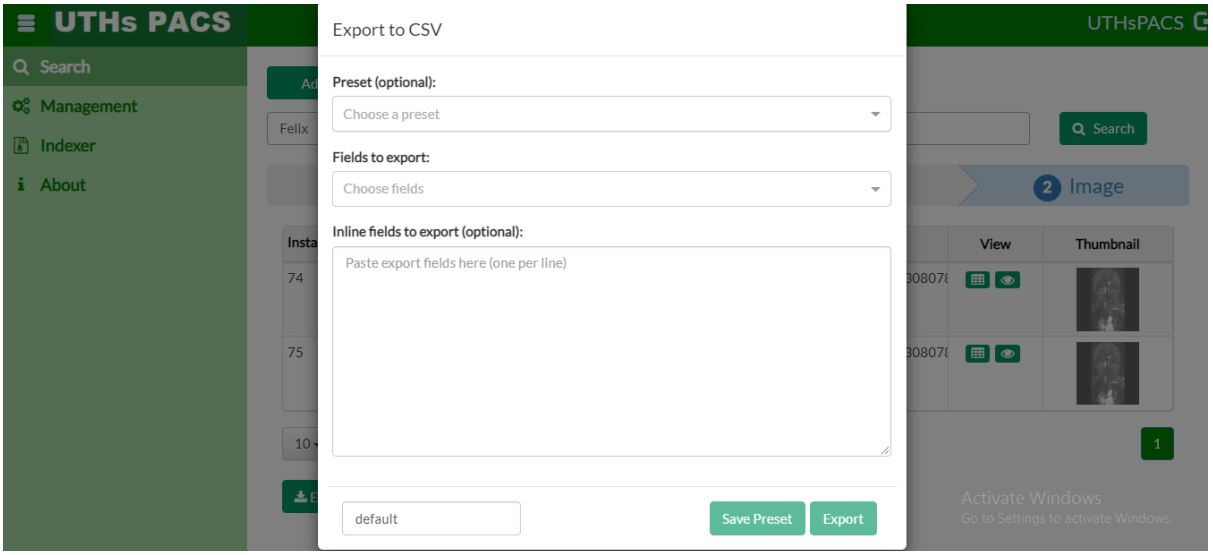

Figure 4.5: Export page

Figure 4.5 Shows the Export page of the Picture Archiving and Communication System where users can export metadata of their choice into a CSV file to a local computer. This file can be shared among medical practitioners whenever there is need to do so.

4.2.2.6 PACS IU Sign up

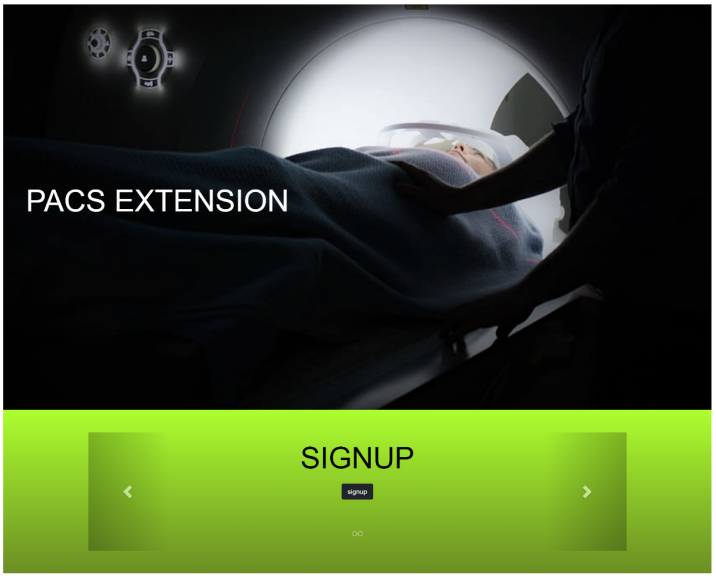

Figure 4.6 : sign up page

4.2.2.7 PACS IU Login

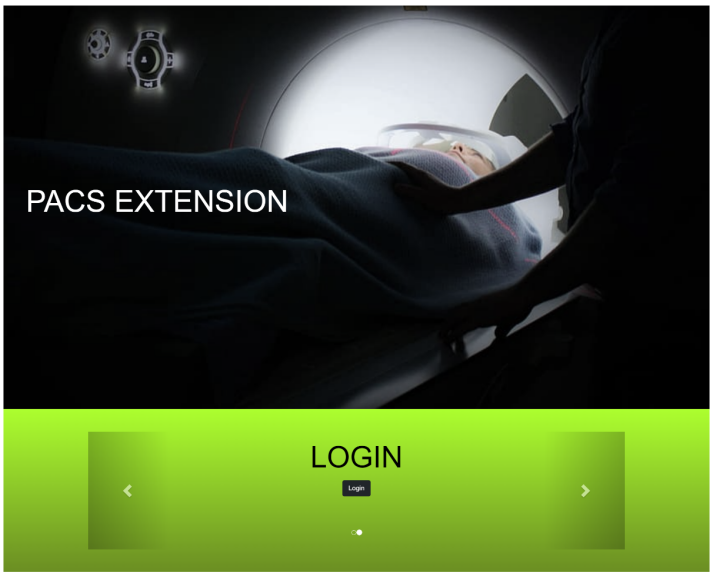

Figure 4.7: login page

4.2.2.8 PACS IU Upload

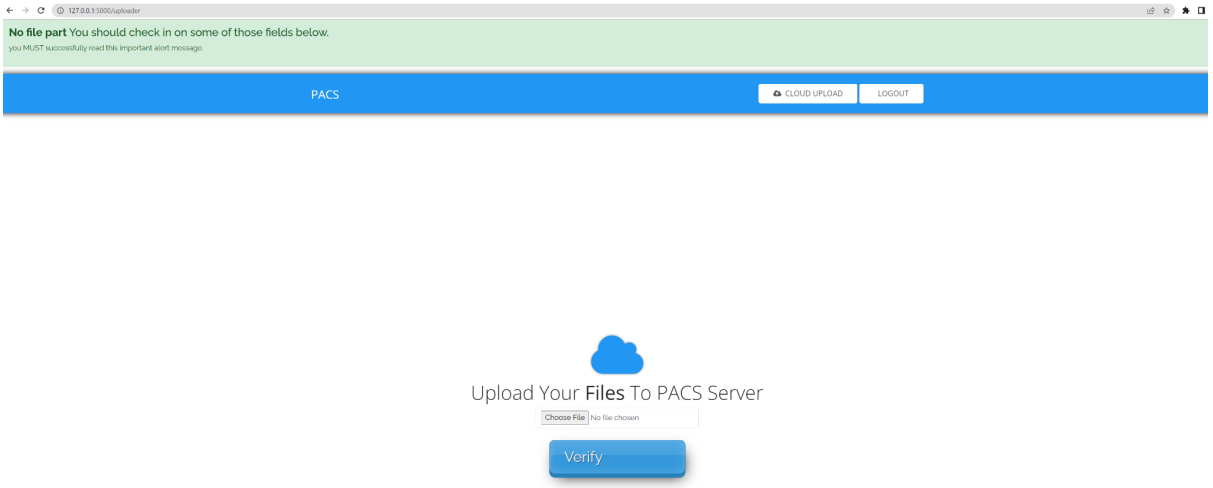

Figure 4.8: Image upload

4.2.2.9 PACS IU Cloud

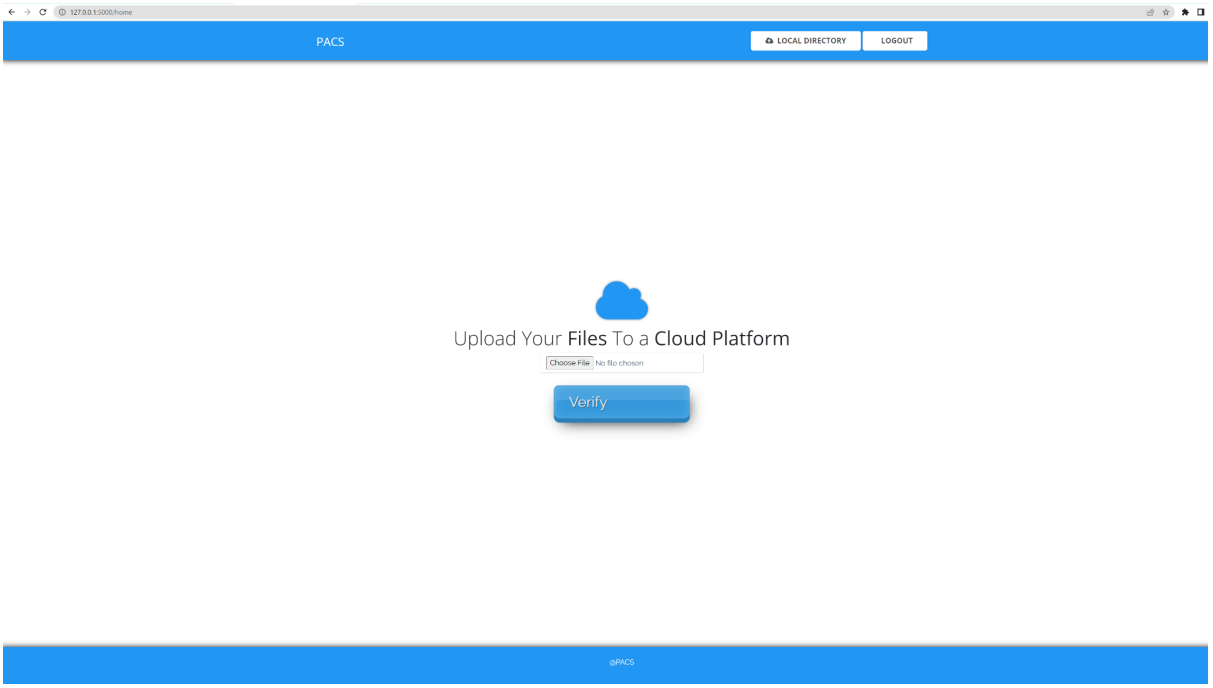

Figure 4.9: Cloud upload

4.2.2.10 PACS IU Metadata Verification

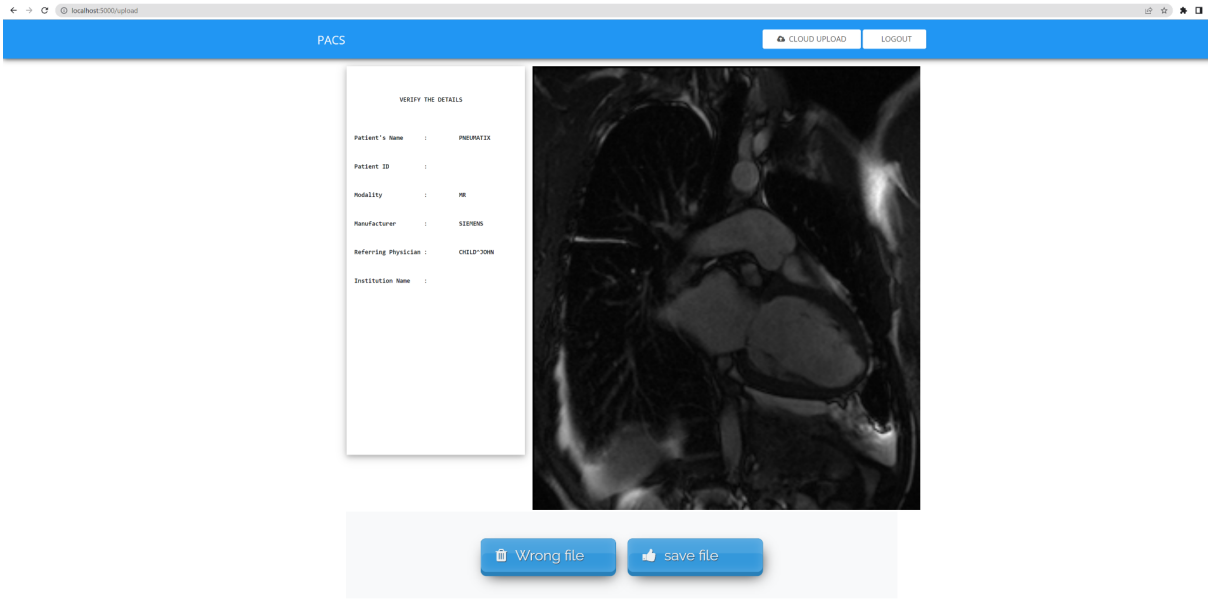

Figure 4.10: Metadata verification

4.3.3 Evaluating the Usefulness and Effectiveness of PACS Platform

The evaluation of the PACS platform's usefulness and Effectiveness was done by presenting the system to radiologists in training at the UTH and giving them clearly outlined tasks that they were required to perform before filling in a questionnaire to indicate their level of satisfaction based on the interaction with the system. This section contains a summary of selected elements from the questionnaire which are directly linked with aspects of the PACS that were being measured.

4.3.3.1 Demographic Details

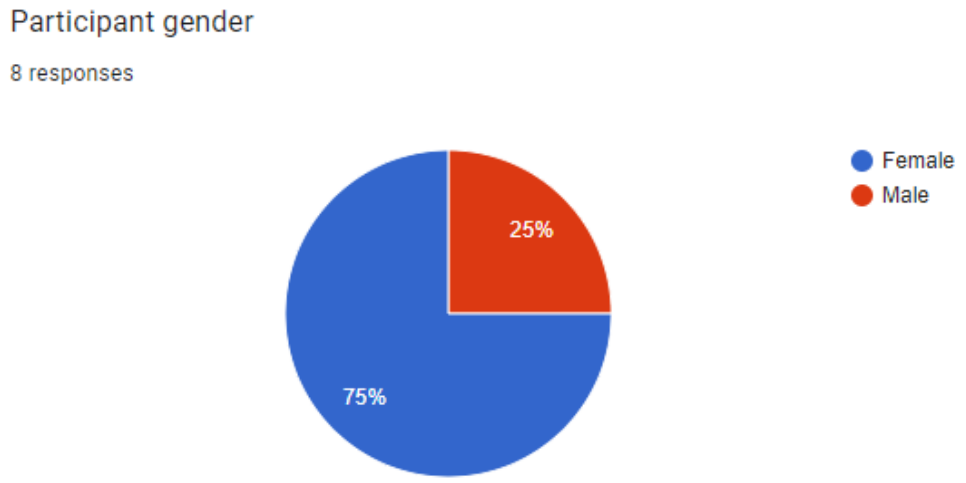

Figure 4.11: Participant gender

Figure 4.11 shows the gender distribution of the study population made up of a total number of 8 radiologists in training at the University Teaching Hospital. 6 participants out of 8 were female and the other 2 were male practitioners.

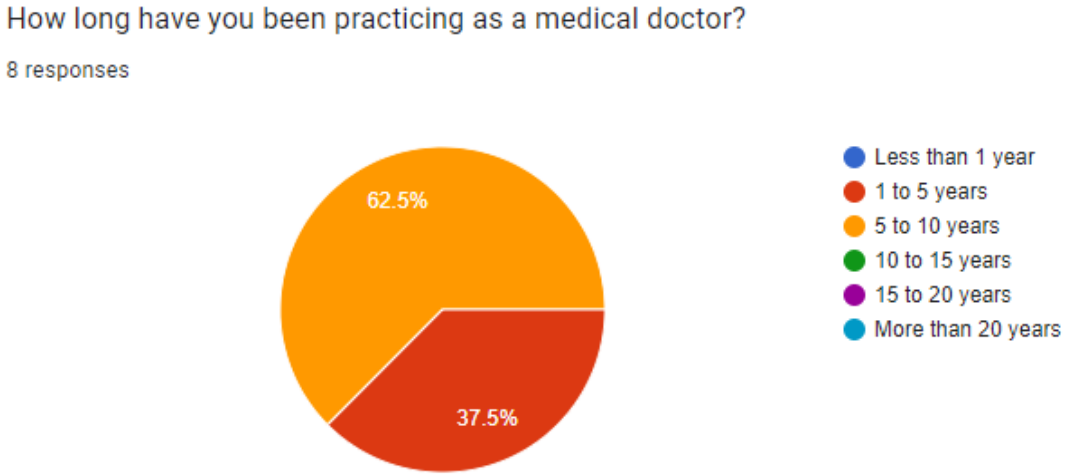

Figure 4.12: Work experience in the field

Figure 4.12 shows the range in the time period the respondents have been practising in their professional field. The majority of the participants had working experience of between 5 to 10 years while others had only been practising for less than 5 years.

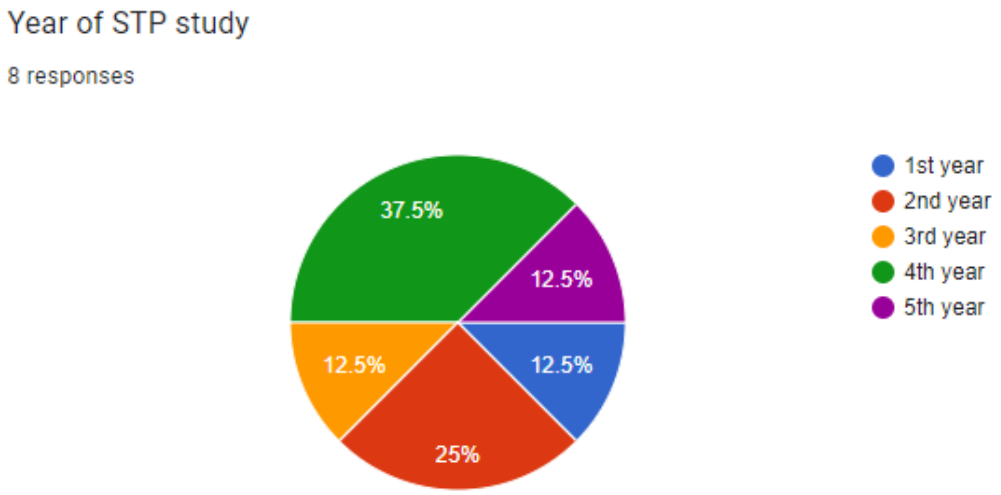

Figure 4.13: Year of STP study

Figure 4.13 shows the current year of STP (specialty training programme) study of the participants. The three of the respondents were in their fourth, two were in their second year while each one of the other three participants were either in their first, third and fifth year of study.

4.3.3.2 Perceived Usefulness

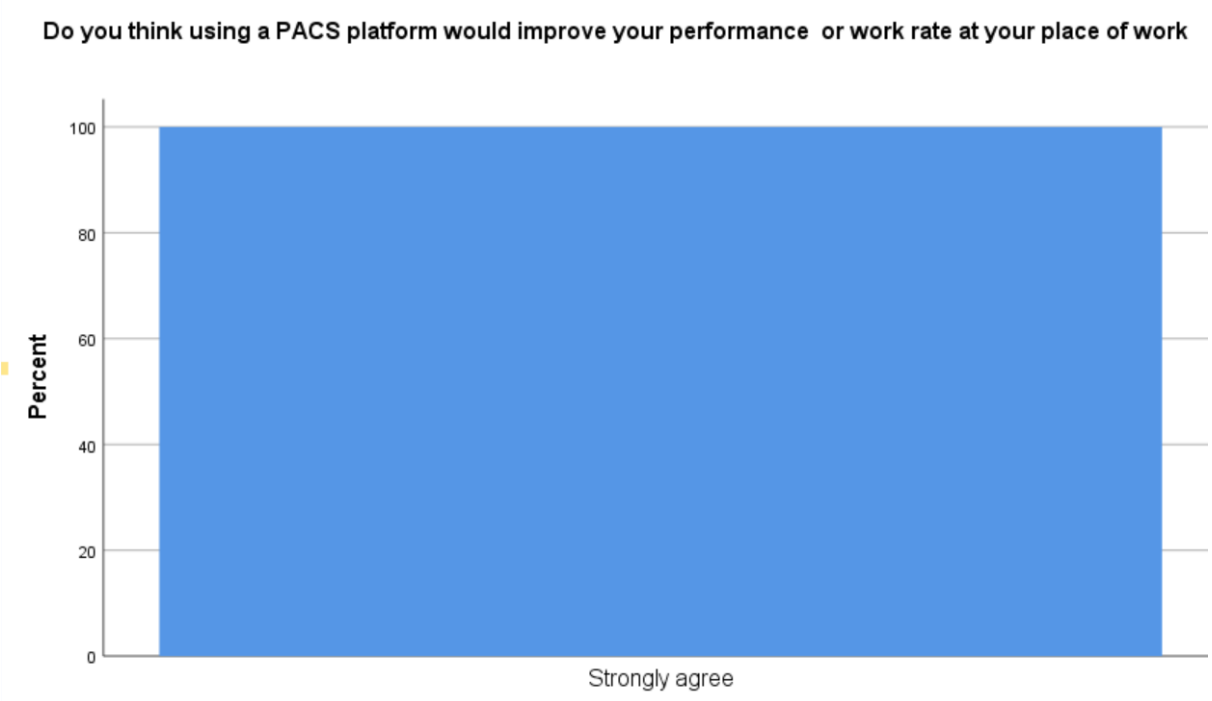

Figure 4.14: Improvement of performance or workrate

Figure 4.14 shows the perceived usefulness of the UTHs PACS in terms of how the platform would affect the user's work rate. All participants strongly agreed that the system would indeed improve the rate at which they carry out their day to day tasks which in turn improves the entire radiological workflow.

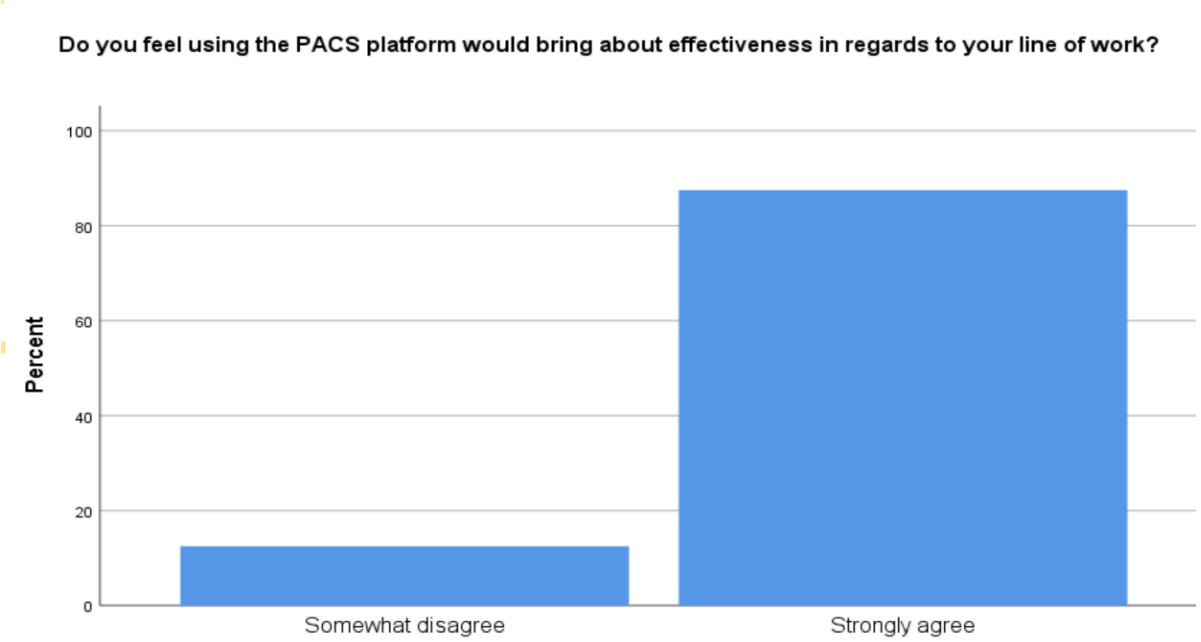

Figure 4.15: UTHs PACS effectiveness

Figure 4.15 shows the perceived usefulness of the UTHs PACS in terms of how the platform would bring about effectiveness in regards to the user's line of work. Seven participants strongly agreed that the system would surely result in a more effective radiological workflow while one participant somewhat disagreed.

4.3.3.3 Perceived Ease of Use

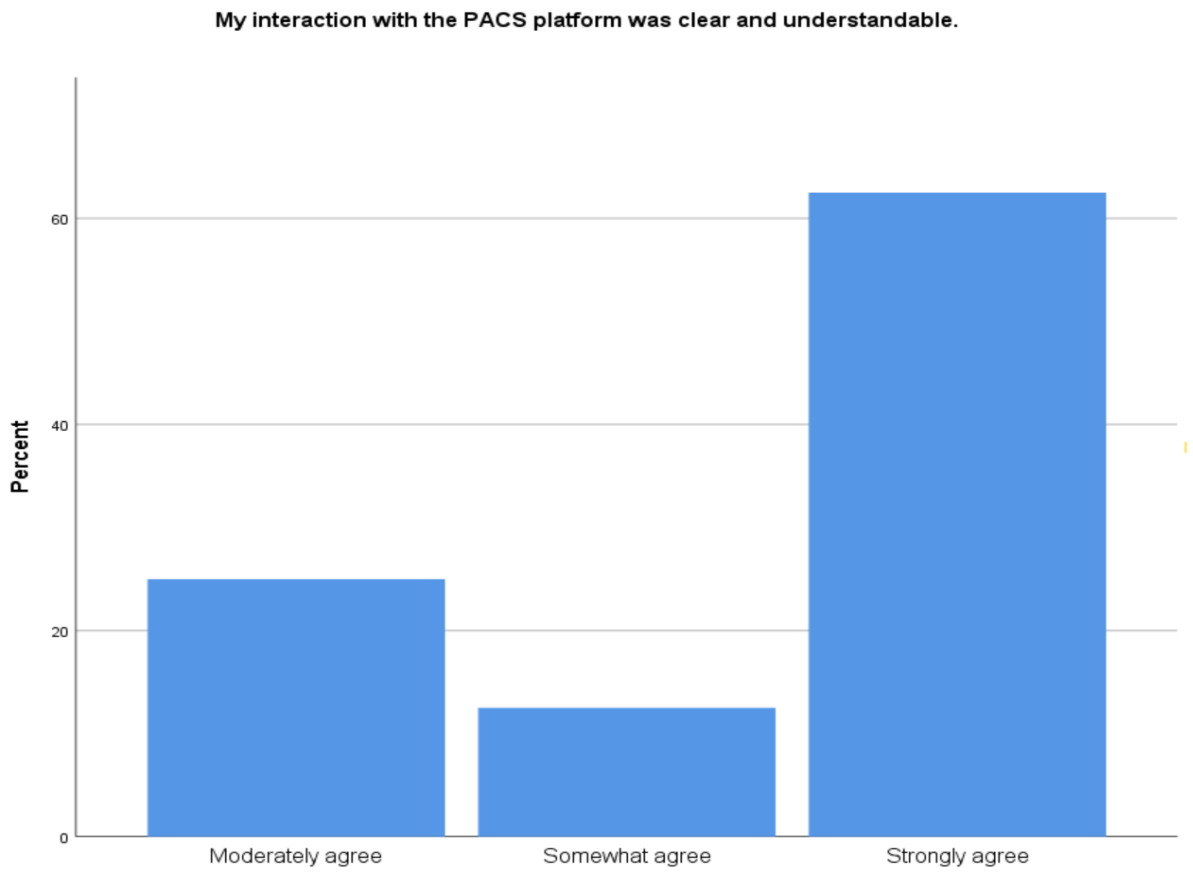

Figure 4.16: Clear and understandable UTHs PACS

Figure 4.16 shows the perceived ease of use of the UTHs PACS with regards to how clear and understandable the system is perceived to be. Five participants strongly agreed, two moderately agreed, one somewhat agreed that the system is indeed clear and understandable.

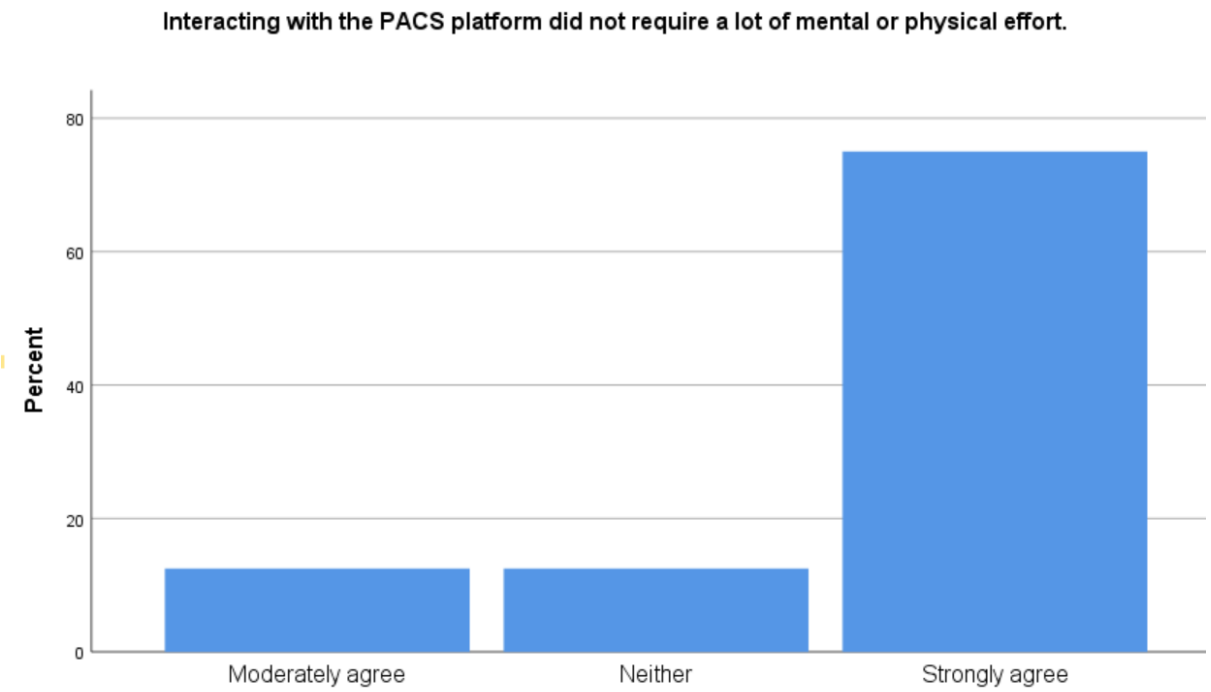

Figure 4.17 Mental and physical effort required to use the PACs

Figure 4.17 shows the perceived ease of use of the UTHs PACS when it comes to effort required to use the system. Six of the eight participants strongly agreed that the system would not require a lot of physical or mental effort to operate while one moderately agreed and the other participant was neither in agreement or disagreement.

4.3.3.4 Job Relevance

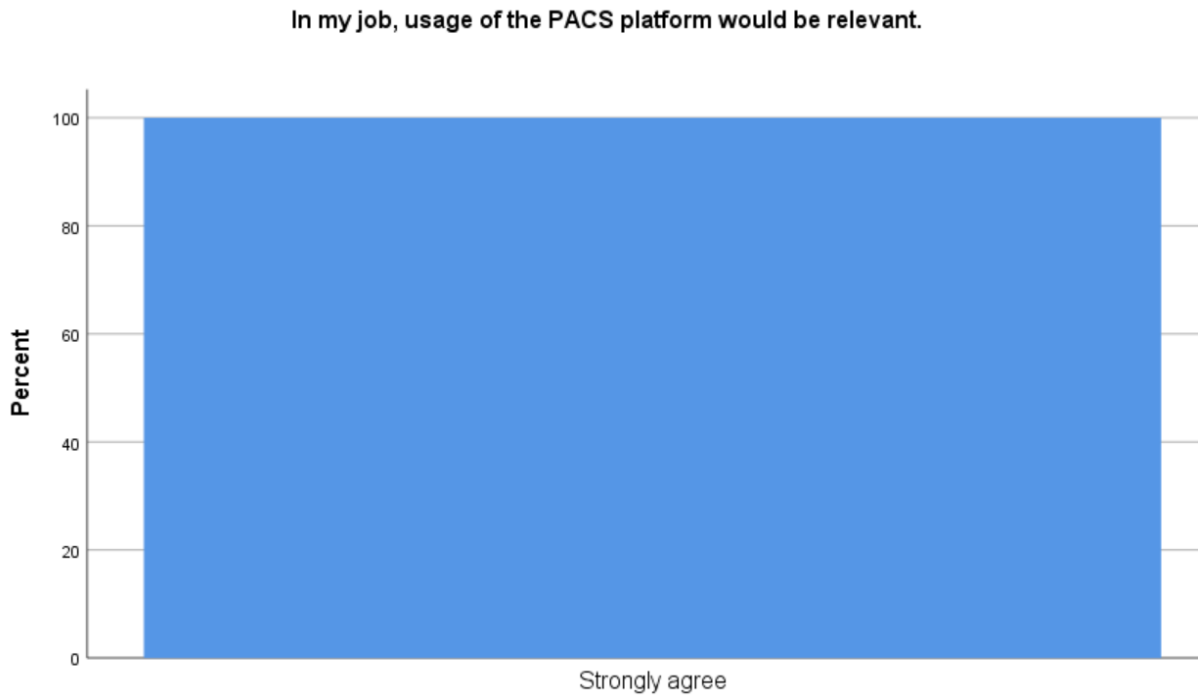

Figure 4.18 UTHs PACS relevance

Figure 4.18 shows how much the users feel the system would be relevant to their job. All participants strongly agreed that the system would be relevant and important in their line of work.

4.3.3.5 Output Quality

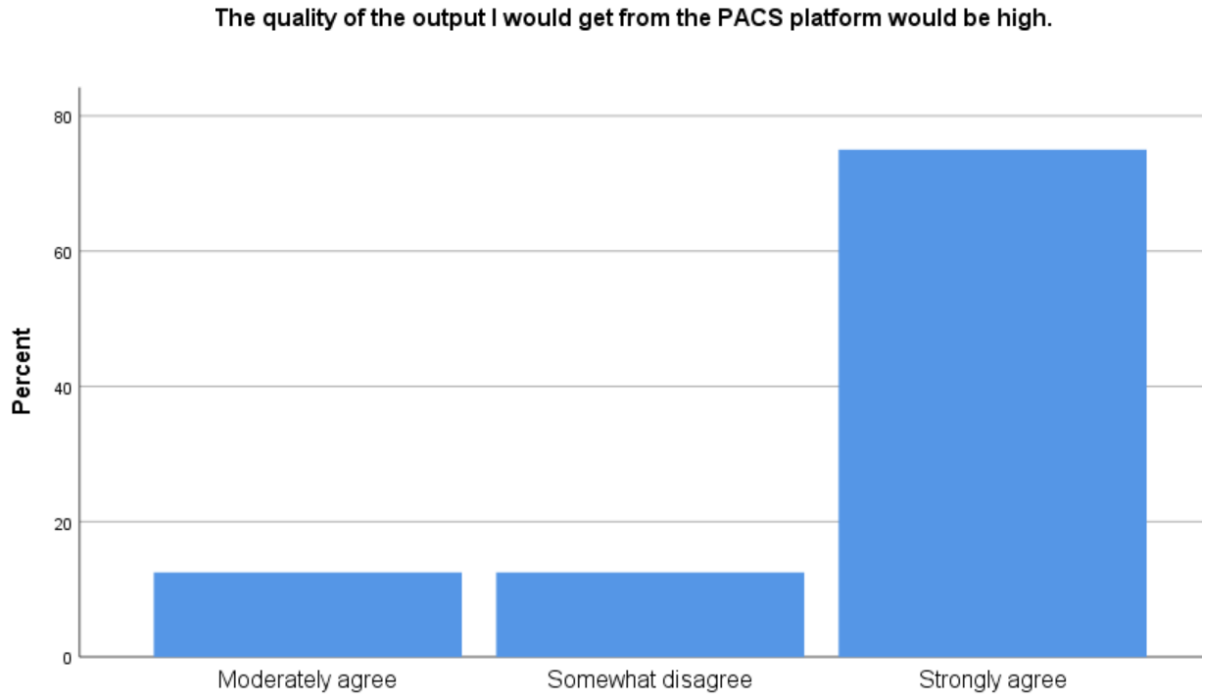

Figure 4.19 High output quality

Figure 4.19 shows how many of the participants feel the level of output quality for the PACS would be high after having interacted with the system. the users have when it comes to the output of the PACS platform. Six of the eight participants strongly agreed that the output quality of the system would be high while one moderately agreed and the other participant somewhat disagreed with this.

5. Discussion

The findings gathered from the study to evaluate the usefulness and effectiveness of the UTHs PACS platform which involved radiologists in training at the University Teaching Hospital revealed a number of interesting factors that link to the performance of the system. These were summarised into the following from the questionnaire:

5.1 Demographics

The results showed that of the eight participants that participated in the study, two were male and six of them were female. The majority of the participants had been practising for about five to ten years while the rest had less than five years of practice in the field which entails that the study population was fairly familiar with the radiological workflow and the challenges that were encountered in the field.

5.2 Perceived Usefulness

The results from the questionnaire revealed that seven out of eight participants agreed that the UTHs PACS would improve the performance at their place of work, bring about effectiveness and overall be a useful tool for the storage of digital radiological images.

5.3 Perceived Ease of Use

The results indicated that all the participants agreed that the PACS platform was easy to use, clear and understandable despite half of these respondents having interacted with a computerised PACS platform for the first time. Users also felt the system did not require a lot of mental or physical effort.

5.4 Job Relevance

The evidence from the results reveal that all participants that took part in the study agreed that the system would be important and relevant in their job.

5.5 Output Quality

The findings revealed that all participants, except one, agreed that the quality of the output they would get from the UTHs PACS platform would be high.

5.6 User Comments

The participants made comments about further improvements that can be made to the system to make it even more useful, effective and easy to use or work with. Users recommended an integration of the PACS platform to an online patient clinical records system that would significantly enhance patient care. Further suggestions were made that the system should have a provision for reporting or exporting images to make it easy for clinicians to share not only patient metadata but the radiological images as well. The users also mentioned the need to incorporate a DICOM image viewer into the system for a more detailed and interactive experience. Lastly, users made comments about the order of the metadata associated with the image on the metadata review page stating that the information should be sorted to prioritise patient pertinent details first as opposed to image technical data such as bit size which a regular user of the platform would normally not be interesting in.

6. Conclusion

This study was aimed at investigating the feasibility of designing and implementing a user-friendly and interoperable Picture Archiving and Communication System (PACS) that will be used for efficient and effective storage of medical images that are produced in public health facilities in Zambia. The study was carried out using data collected from radiologists and radiographers at LMUTH and the UTHs. The study sought to gather information crucial to the implementation of a PACS system for digital storage of radiological images by taking into account factors such as the current methods of storing images at the University Teaching

Hospitals, the format in which these images are stored and the process that is used to retrieve the images. The key observations from the research were that the current storage of images is done using CDs, films and hard-drives or flash disks and these radiographs or films are stored in store rooms while softcopy images are stored on external hard-drives and some images go back with the patient because of low storage capacity at the Hospitals. In cases where images were needed for use, retrieval is done by going through the stored images in the darkroom and searching for patient name/record ID and this analog method of image storage and retrieval had proven to be time consuming and somewhat ineffective when dealing with a large number of images. Therefore, the aim of the project team was to improve the storage aspect of the radiological workflow by coming up with an interoperable Picture Archiving and Communication system capable of storing images on a local machine and on the cloud.

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7. Appendix A: Interview Questions, Responses and Tam Questionnaire

Table A.1: Interview Questions

RADIOLOGISTS	RADIOGRAPHER
1. How long have you been working here? 2. Where else have you worked before or are currently working for any other institution apart from this institution?	1. How long have you been working here? 2. Where else have you worked before or are currently working for any other institution apart from this institution?
3. In what state are the radiological images being stored? 4. How are digital radiological images being (a) Stored (b) Retrieved 5. Are there any instances that require you to access or retrieve previously stored (digital) images? 6. Is there a policy stating how long medical images ought to be stored and when they can be discarded? 7. What are the disadvantages of not effectively storing images to (a) patients	1. What processes do you follow in order to produce digital radiological images? 2. How are radiological images stored and retrieved? 3. In what format are radiological images stored? 4. Are there any instances that require you to access and retrieve previously stored Radiological images?

(b) radiologists	

Table A.2 Interview Responses

NAME	DEMOGRAPHIC DETAILS	COMMENTS	CURRENT STORAGE	FORMAT
Radiographer 1	Over 5 years experience working as a radiographer at the UTH	Radiology mostly doesn't remain with any records /photo which makes it hard to retrieve Analog has (silver recovery) recycling	External hard drives, films are used and stored in basement	analog/digital
Radiographer 2	Over 5 years experience working as a radiographer at the UTH	Only retrieve images on patient requests to do so	Computer for digital x rays..and in the store room	analog/digital
Radiographer 3	Over 5 years experience working as a radiographer at the UTH	Capacity needs to be improved for storage purposes	Films, patients move with them and hard drives	Analog/digital

Radiographer 4	7 years experience and counting as a radiographer and worked a year plus at Levy Hospital before coming to UTH (cancer hospital)	Accessing images is hard as they're a lot of files to check through	CDs, films and PACS(Dicom)	Analog /digital

NAME	**DEMOGRAPHIC DETAILS**	**COMMENTS**	**RETRIEVAL METHOD**
Radiologist 1	7 years experience and counting as a radiologist at Levy Mwanawasa Hospital4 years experience working as registrar in radiology	Images should not be discarded for the purpose of further study or research just like the one being carried out by the researchers and legal matters that may arise at the hospital Currently CDs and films are used for storage and capacity is a problem. Hence patients carry the CDs and films with them. Which makes it difficult to do follow up because CDs get scratched which makes it difficult or rather hard to know progression of disease.	Analog /digital

Radiologist 2	5 years experience and counting as a radiologist at UTH	Since the storage rooms run out , the hospitals discard the images and give the films to recyclers that extract the silver from the film (silver recovery).	

Demographics
- Participant's gender
- How long have you been practicing as a medical doctor?
- Year of STP study
- Have you ever interacted with a computerized PACS platform?

Intention to Use
- Assuming you had access to a PACS platform, would you use it?
- Would you recommend other Doctors to use the PACs platform?

Perceived Usefulness
- Do you think using a PACS platform would improve your performance or work rate at your place of work
- Do you feel using the PACS platform would bring about effectiveness in regards to your line of work?
- Would you find the PACS platform to be a useful tool in your line of work?

Perceived Ease of Use
- My interaction with the PACS platform was clear and understandable.
- Interacting with the PACS platform did not require a lot of mental or physical effort.
- I would find the PACS platform to be easy to use.
- I would find it easy to get the PACS platform to do what I want it to do.

Subjective Norm
- My supervisors would allow me to use the PACS platform.
- My patients would benefit from my use of the PACS platform.

Voluntariness
- My use of the PACS platform would be voluntary.
- My supervisor would not require me to use the PACS platform.

Job Relevance
- In my job, usage of the PACS platform would be important.
- In my job, usage of the PACS platform would be relevant.

Output Quality
- I had no problem with the quality of the PACS platform's output.
- The quality of the output I would get from the PACS platform would be high.

Result Demonstrability
- The results of using the PACS platform would be positive to me.
- I believe I could communicate to others the benefits of using the PACS platform.
- I would have no difficulty telling others about the results of using the PACS platform.
- Do you have any comments and/or suggestions on the PACS platform for future improvements?

Figure A.1 TAM Questionnaire

8. Appendix B: Ethical Clearance Approval

NATIONAL HEALTH RESEARCH AUTHORITY
Paediatric Centre of Excellence, University Teaching Hospital, P.O. Box 30075, LUSAKA
Chalala Office Lot No. 18961/M, Off Kasama Road, P.O. Box 30075, LUSAKA
Tell: +260211 250309 | Email: znhrasec@nhra.org.zm | www.nhra.org.zm

Ref No: NHRA000024/10/05/2022 **Date: 10th May, 2022**

The Principal Investigator,
Ernest Obbie Zulu,
University of Zambia
Lusaka, Zambia.

Dear Ernest Obbie Zulu,

Re: Request for Authority to Conduct Research

The National Health Research Authority is in receipt of your request for authority to conduct research titled **"Enterprise Medical Imaging for Streamlined Radiological Diagnosis in Zambian Public Health Facilities."**

I wish to inform you that following submission of your request to the Authority, our review of the same and in view of the ethical clearance, this study has been **approved** on condition that:

1. The relevant Provincial and District Medical Officers where the study is being conducted are fully appraised;
2. Progress updates are provided to NHRA quarterly from the date of commencement of the study;
3. The final study report is cleared by the NHRA before any publication or dissemination within or outside the country;
4. After clearance for publication or dissemination by the NHRA, the final study report is shared with all relevant Provincial and District Directors of Health where the study was being conducted, University leadership, and all key respondents.

Yours sincerely,

Prof. Godfrey Biemba
Director/CEO
National Health Research Authority

Figure B.1 NRHA Ethical Clearance Approval

UNIVERSITY OF ZAMBIA
BIOMEDICAL RESEARCH ETHICS COMMITTEE

Telephone: +260 977925304
Telegrams: UNZA, LUSAKA
Telex: UNZALU ZA 44370
Fax: + 260-1-250753
Federal Assurance No. FWA00000338

Ridgeway Campus
P.O. Box 50110
Lusaka, Zambia
E-mail: unzarec@unza.zm
IRB00001131 of IORG0000774

5th May, 2022

Your REF. No. 2731-2022

Dr. Ernest Obbie Zulu,
University of Zambia,
Department of Library and Information Science,
Lusaka.

Dear Dr. Zulu,

RE: ENTERPRISE MEDICAL IMAGING FOR STREAMLINED RADIOLOGICAL DIAGNOSIS IN ZAMBIAN PUBLIC HEALTH FACILITIES (REF. NO. 2731-2022)

The above-mentioned research proposal was presented to the Biomedical Research Ethics Committee on 5th May, 2022. The proposal is **approved**. The approval is based on the following documents that were submitted for review:

a) Study proposal
b) Questionnaires
c) Participant Consent Form

APPROVAL NUMBER : REF. 2731-2022

This number should be used on all correspondence, consent forms and documents as appropriate.

- **APPROVAL DATE : 5th May 2022**
- **TYPE OF APPROVAL : Fast Track**
- **EXPIRATION DATE OF APPROVAL : 4th May 2023**
  After this date, this project may only continue upon renewal. For purposes of renewal, a progress report on a standard form obtainable from the UNZABREC Offices should be submitted one month before the expiration date for continuing review.
- **SERIOUS ADVERSE EVENT REPORTING**: All SAEs and any other serious challenges/problems having to do with participant welfare, participant safety and study integrity must be reported to UNZABREC within 3 working days using standard forms obtainable from UNZABREC.
- **MODIFICATIONS**: Prior UNZABREC approval using standard forms obtainable from the UNZABREC Offices is required before implementing any changes in the Protocol (including changes in the consent documents).
- **TERMINATION OF STUDY**: On termination of a study, a report has to be submitted to the UNZABREC using standard forms obtainable from the UNZABREC Offices.

Figure B.2 UNZABREC Ethical Clearance Form

All Correspondence should be addressed to the
Permanent Secretary
Telephone: +260 211 253040/5
Fax: +260 211 253344

REPUBLIC OF ZAMBIA
MINISTRY OF HEALTH

In reply please quote:
MOH/
No.....

NDEKE HOUSE
P. O. BOX 30205
LUSAKA

16th May, 2022

Obbie Zulu
LUSAKA

RE: REQUEST FOR AUTHORITY TO CONDUCT RESEARCH

Reference is made to your letter dated 25th April, 2022 in which you requested the Ministry, for permission to conduct a research titled "***Enterprise Medical Imaging for Streamlined Radiological Diagnosis in Zambia Public Health Facilities***". I wish to inform you that my office has no objection to this request provided that;

1. The relevant Institution Director where the study is being conducted are fully appraised;
2. The final study report is cleared by NHRA before any publication or dissemination within or outside the country; and
3. After clearance for publication or dissemination by NHZRA, the final study report is shared with the Ministry.

Kindly ensure minimum interruption in health service delivery to the selected health you will undertake your research.

By copy of this letter, the Provincial, District Health Offices and facilities are advised to allow you undertake the above mentioned research and provide you with the relevant support.

Yours faithfully

Prof. Lackson Kasonka
Permanent Secretary- Technical Services
MINISTRY OF HEALTH

Figure B.3 MINISTRY OF HEALTH Ethical Clearance Form

REPUBLIC OF ZAMBIA
MINISTRY OF HEALTH
University Teaching Hospitals -Adult

Fax: +260 211 250305
e-mail: mduth@yahoo.com

P/Bag Rw 1X
Lusaka - Zambia
Tel: +260 211 253947 (Switch Board)
+260 211 251451

OFFICE OF THE SENIOR MEDICAL SUPERINTENDENT

Our Ref:

Your Ref:

5th September, 2022

Dr. Ernest Obbie Zulu
University of Zambia
Department of Library & Information Science
P O Box 50110
LUSAKA

Dear Dr. Zulu,

RE: REQUEST FOR AUTHORITY TO CONDUCT RESEARCH

The University Teaching Hospital – Adult is in receipt of your letter dated 5th September, 2022 in which you had requested to conduct a research titled ***"Enterprise Medical Imaging for Streamlined Radiological Diagnosis in Zambia Public Health Facilities" at the University Teaching Hospital."***

I wish to inform you that permission has been granted and you are advised to liaise with the Head of Department.

Yours faithfully,

Dr. Mwila Lupasha
Head Clinical Care
for/**Senior Medical Superintendent**
UNIVERSITY TEACHING HOSPITALS - ADULT

Figure B.4 UTH Ethical Clearance Form

TO: The Head Clinical Care (HCC)
Levy Mwanawasa University Teaching Hospital
P.O. Box 340081
Chainama Hills, Great East Road
Lusaka, Zambia, 10101

UFS: The Head of Department–Radiology Department
Levy Mwanawasa University Teaching Hospital
P.O. Box 340081
Chainama Hills, Great East Road
Lusaka, Zambia, 10101

Approved
by HCC
14/06/22

REPUBLIC OF ZAMBIA
MINISTRY OF HEALTH
LEVY MWANAWASA UNIVERSITY TEACHING HOSPITAL
14/06/2022
MAY 2022
Supported
DR J. SIMUMA
RADIOLOGY DEPT
P.O. BOX 34081, LUSAKA

May 12, 2022

REF: REQUEST FOR ACCESS TO PATIENTS' OLD RADIOLOGY REPORTS AND IMAGES FOR THE PURPOSE OF SYSTEMATICALLY ORGANIZING THEM TO FACILITATE THEIR EFFICIENT STORAGE AND RETRIEVAL AS PART OF A PILOT RESEARCH PROJECT — ENTERPRISE MEDICAL IMAGING FOR STREAMLINED RADIOLOGICAL DIAGNOSIS IN ZAMBIAN PUBLIC HEALTH FACILITIES.

Dear Sir,

I am a fourth year Specialty Training Programme (STP) student in Radiology (ID number STPRAD 19010107) at the UTHs Adult hospital. I am collaborating with Dr. Lighton Phiri from the University of Zambia in conducting the pilot study mentioned above, under the UNZA DRGS. I hereby request for access to patients' old radiology reports and images stored in the library/department at this hospital. We have proposed, in our study, to digitise and digitalise historical medical image data collected in public health institutions in Zambia in order to enhance efficient management and retrieval of the reports and images. The study has been approved by UNZABREC and NHRA (References: UNZA-2731-2022 and NHRA000024/10/05/2022).

The accessed data (images and reports) will be kept confidential before, during and after the digitisation process and the final package shall be handed over to the Head of Department, Radiology.

Ernest Obbie Zulu, MBChB
Mobile: +26 097 7 199434; Email: obbiernest@gmail.com

Figure B.5 LMUTH Ethical Clearance Form