# Enterprise Medical Imaging for Improved Radiological Workflows: Towards an Interoperable and Standards-Based Medical Imaging Platform in Public Health Facilities in Zambia

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## Abstract

In recent years, there has been a gradual rise in the number of radiological imaging examinations in the health sector due to a high disease burden in the expanding population. This has led to an exponential growth of medical imaging data requiring interpretation and management. Furthermore, the sheer quantity of radiological reports generated by Radiologists has also increased. However, public health facilities in Zambia do not have the requisite technological infrastructure necessary to efficiently and effectively store, manage and access medical images and radiological reports. This paper discusses preliminary work conducted to highlight the implications and challenges of the non-existence of a Picture Archiving and Communication System (PACS)—a crucial component of an Enterprise Medical Imaging (EMI) strategy—and, additionally, an outline of how a PACS platform could potentially address the challenges. An archival records analysis was conducted on historical medical images produced at two University Teaching Hospitals (UTHs) by digitising sample X-ray images archived on compact discs and additionally, medical images archived on external drives. The paper also outlines how existing historical images could potentially be stored, managed and accessed using a PACS platform.

## 1. Introduction

Radiological imaging is an essential component of the entire healthcare continuum, from screening to diagnosis, treatment planning, therapeutic intervention, monitoring and follow-up of health conditions. Due to a high disease burden in the expanding population, recent years have seen a gradual rise in the number of radiological imaging examinations requested and performed, with a corresponding increase in the sheer quantity of radiological reports generated by Radiologists in the health sector. This has led to an exponential growth of medical imaging data in the form of images and reports requiring interpretation and management. Further, in order to optimise the quality and value of radiological reports, Radiologists are required to conduct a comparative analysis of current and previous study findings. Thus, storage of and access to old imaging data (images and reports) is crucial.

However, public health facilities in Zambia do not have the requisite technological infrastructure necessary to efficiently and effectively store, manage and access the medical images and radiological reports. The ongoing phased replacement of film-based radiology with digital radiology in public health facilities is increasingly making necessary the need to develop and implement an efficient platform for historical images archival and retrieval such as a Picture Archiving and Communication System (PACS)—a crucial component of an Enterprise Medical Imaging (EMI) strategy.

This work was aimed at understanding how medical images are currently stored and accessed in public health facilities in Zambia and, additionally, demonstrate how EMI could be leveraged to facilitate effective access and storage of medical images. The remainder of this paper is organised as follows: Section 3 synthesises existing literature related to this work, while Section 4 describes the methodological approach used in this work. The findings and discussion for this work are outlined in Section 5 and, finally, Section 6 presents the conclusions and potential future directions of this work.

## 2. Related Work

### 2.1. Zambia eHealth Strategies and Policies

The government of the republic of Zambia through the Ministry of Health has implemented eHealth strategies since 2013, aimed at providing guidelines on how to use ICT to leverage health service delivery through successful implementation of eHealth systems. This implementation is based on the proven potential that ICT has in transforming healthcare delivery by enabling information access, making healthcare systems more efficient and supporting healthcare operations, management and decision making. The emphasis in the second and current eHealth strategy document (2017 – 2021) (Republic of Zambia - Ministry of Health, 2016) is interoperability among digital health initiatives aimed at enhancing data accuracy and exchange. The document also outlines the pillars of the strategy, being service delivery, research and eLearning. These focus areas were formulated to promote development and implementation of efficient eHealth solutions for quality health service delivery, to increase the use of technology tools in health research and to reach more healthcare stakeholders through the use of technology.

### 2.2. Radiological Workflows

Radiological workflows constitute the step-by-step processes and procedures followed in the end-to-end process of radiological examination from ordering through to report dispatch. According to Godinho et al, the basic workflow in a radiology department involves three major stages; Admission, Examination and Payment (Godinho et al., 2015). In a modern day radiology department, admission (which involves patient registration and scheduling), payment and report dispatch interact with the Radiology Information System (RIS). The examination stage — which interacts with the Picture Archiving and Communication System (PACS) consists of image acquisition, image revision and report generation. During this stage, devices are used to acquire the images which are deposited into the PACS repository. The Radiologist then views the stored images, analyses them and generates a radiological study report. A well-orchestrated radiological workflow has the potential to optimise the efficiency of an imaging enterprise. Redfern et al evaluated the changes in workflow and efficiency of radiologists and technicians in various

clinical settings in the radiology department after the introduction of a PACS (Redfern et al., 2000). Their findings showed that although there was slowing down of the technician's workflow (related to the quality control procedures), there was significant shortening of the radiologist examination review time after the introduction of PACS.

### 2.3. Enterprise Medical Imaging

Enterprise Medical Imaging (EMI) is a combination of techniques, processes and procedures for facilitating the effective collection, storage, management, distribution and analysis of clinical imaging content in health settings, whose purpose is to ensure effective integration of technological components involved in the end-to-end medical imaging workflows. Petersilge states that EMI has the potential to improve clinical care and operational efficiency of health institution programmes and services (Petersilge, 2019). Further, Roth et al states that an Enterprise Imaging Platform is a key element of any EMI strategy (Roth et al., 2016). Central to the platform is a storage repository such as a Picture Archiving and Communication System (PACS). The broadening spectrum of medical imaging modalities and, therefore, increased imaging data necessitate the implementation of an effective PACS platform.

### 2.4. Free and Open Source Picture Archiving and Communication Platforms

In the last couple of years, significant advances have been made in the field of Medical Imaging. Specifically, there has been an increase in the types of modalities and, additionally, the rate at which medical images are generated. Correspondingly, there has been a global increase in the trends in use of Medical Imaging, with a retrospective study by Smith-Bindman et al. highlighting this continued increase in North America (Smith-Bindman et al., 2019). In order to facilitate affordable and effective access and storage of large datasets of Medical Images, a number of PACS platforms have been designed and implemented, with open source PACS platforms providing unique opportunities for developing countries as they still attempt to address more pressing concerns associated with major shortages of imaging equipment and human resources (Frija et al., 2021).

A number of open source PACS platforms have been proposed, with all of them providing a cost effective way of medical image acquisition, management, storage and access. However, the design and implementation of the PACS platforms differs in a number of ways. In their analysis of existing open source PACS platforms, Widel and Spinczyk performed a detailed analysis of three open source PACS platforms (Wideł & Spinczyk, 2016) out of the 11 that were available for analysis, with their detailed analysis primarily focused on usability and functionality (*PACS Server*, n.d.).

In this work, the Dicoogle framework (Lebre et al., 2020) was used to demonstrate the viability of using open source PACS platforms. Dicoogle was selected for its modular architecture and its relatively low entry installation and configuration barrier.

## 3. Methodology

The research methodology used to undertake this work employed a mixed methods approach, involving a retrospective analysis of current practices associated with Medical Image

storage—Section 4.1—and the setting up and configuring of a Dicoogle PACS server—see Section 4.2.

### 3.1. Situation Analysis

A retrospective records review of historical Medical Images was conducted. Historical Radiography and Ultrasound studies archived on CDs and External Hard Drives were digitised, compiled and analysed. The digitised images were collected from the Radiology Departments at the Levy Mwanawasa University Teaching Hospital (Radiographs only) and Adult Hospital of the University Teaching Hospitals (Radiographs and Ultrasound).

In order to analyse Medical Images archived on CDs, two Research Assistants were hired to export the DICOM files from the CDs. RadiAnt DICOM viewer version 4.0.1[1] was installed on computers running Windows 7 and 10 operating system software[2]. The historical medical images stored on CDs were then exported in DICOM format to the project external hard drives using the installed RadiAnt DICOM viewer. Images stored on external hospital hard drives were copied to the project drives before digitisation and analysis.

### 3.2. Preliminary Requirements for Picture Archiving and Communication System

The situational analysis outlined in Section 3.1 and observations made by one of the authors identified Physicians, Radiographers and Radiologists as the primary actors who would interact with the PACS system as follows:

- Physicians—Upon requisition for examinations to be performed, Physicians would generally require subsequent access to medical images produced and deposited into the PACS platform
- Radiographers—Radiographers are technicians primarily responsible for acquisition of medical images, during examination of the patient and would have to deposit the medical images into the PACS platform
- Radiologists—Radiologists need to be able to access medical images deposited into the PACS platform in order for them to interpret the medical images

Figure 1 is a context diagram that illustrates how the three actors would interact with the PACS platform and, additionally, how the PACS platform would be interfaced with external systems and services.

In order to assess the feasibility of setting up a PACS platform and, additionally, demonstrate how the PACS platform would help address medical image workflow challenges resulting from the current manual workflows employed at the UTHs, a prototype PACS platform was implemented using the Dicoogle open source PACS archive software (Lebre et al., 2020). The Dicoogle platform was installed on a 64-bit Ubuntu 22.04 LTS[3] platform, with 12GB RAM and running OpenJDK 11.0.16[4].

[1] https://www.radiantviewer.com
[2] https://www.microsoft.com/en-us/windows
[3] https://releases.ubuntu.com/20.04
[4] https://openjdk.org

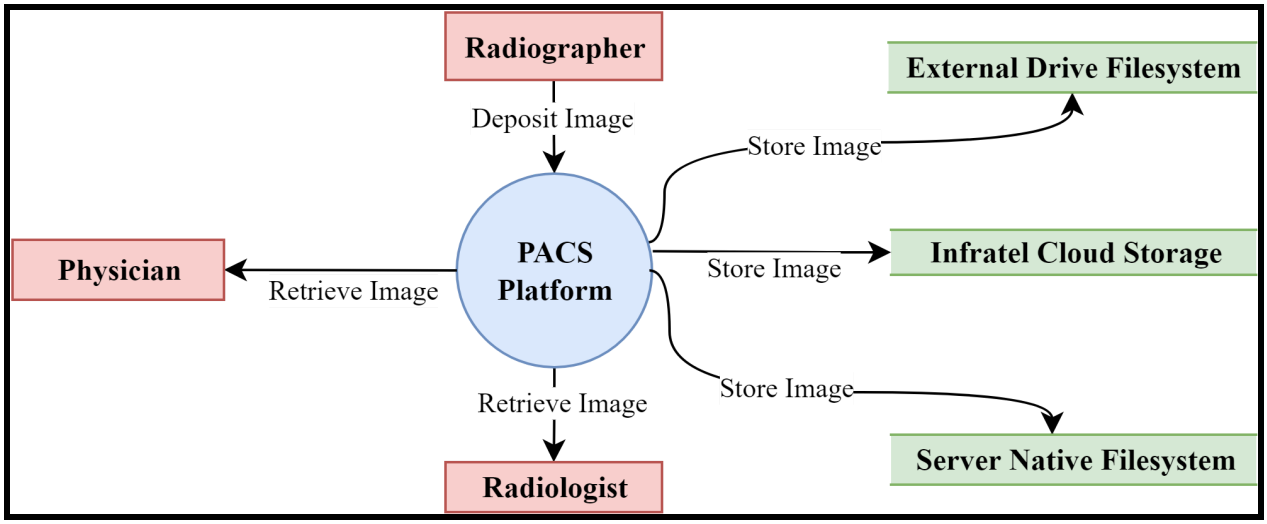

Figure 1: Context Diagram Illustrating PACS Platform, Entities and Data Stores

## 4. Results and Discussion

This section presents and discusses the findings from the situational analysis and implementation of the prototype PACS platform, outlined in Sections 4.1 and 4.2 respectively.

### 4.1. Current Medical Image Workflows, Storage, Management and Access

#### *4.1.1. Radiological Workflows at UTHs*

In spite of the availability of digital and DICOM compatible image acquiring equipment, the current radiological workflows at the UTHs are manual, characterised by non-existence of RIS or PACS platforms. This poses a number of challenges including poor examination requests management, increased workload, long patient waiting times, increased examination rejects and repeats, difficult retrieval of historical images and reports, redundant and repetitive workflow steps, long report turnaround times, and a pile up of undispatched final reports. This scenario gives an insight into the probable status quo of the current radiological workflows in public health facilities in Zambia generally. (Zulu & Phiri, 2022).

#### *4.1.2. Medical Image Storage, Management and Access*

As stated earlier, historical images and reports are crucial in the improvement of the quality and value of radiological reports. Their review is necessary in follow-up examinations for comparative analysis of disease interval changes, in post-treatment cases for monitoring of disease recurrence, in postoperative cases for assessment of residual disease and in postoperative assessment of success of corrective procedures.

Currently at the UTHs, radiographers store the digital images randomly on compact discs (CD's), DVD,s and external hard drives. Frequently the department experiences short supplies of the discs leading to clients being requested to purchase their own as they report for examination, which is an added cost to the clients. Storage of sectional imaging studies with large amounts of data – such as Computed Tomography (CT), remarkably slows down the review process and analysis of the images by radiologists as loading of the images from the compact discs onto the

viewing platforms is time consuming. A practice that is often encouraged is for the requesting physicians to review the source images and radiological reports side-by-side. For this reason, the discs on which images are stored are dispatched together with the reports. In an effort to retain records of the studies, the radiology department back-up the images on DVD's and external hard drives. There is currently a large amount of radiological images data estimated to be in excess of 20 terabytes stored on different hardware including DVD's, CD's, external hard drives, an old image server and office desktop computers in different places within the department. These images are seldom systematically stored and are characterised by unnamed non hierarchical folders, inconsistencies in image back-up formats including non-DICOM formats and repeated back-ups. Incidences of loss of the images through cleanup of data from the equipment before back-up is performed and theft of storage hardware are commonplace.

The implications posed by these challenges, therefore, are vast. Firstly, it is almost impossible for radiologists to retrieve historical images in order to conduct comparative image analysis for evaluation of interval changes. Secondly, there is no objective tracking of the amount of radiation exposure to the clients as records of previous exposures are not readily available. Thirdly, there is a lack of collection of accurate epidemiologically significant statistics, a key requirement for departmental and hospital decision making, and for influencing national health policy on medical radiation. Fourthly, the loss of image-containing hardware through theft may lead to breach of patient confidentiality with serious medico legal consequences and litigation against the department and/or the hospital.

### 4.2. Prototype Picture Archiving and Communication System Platform

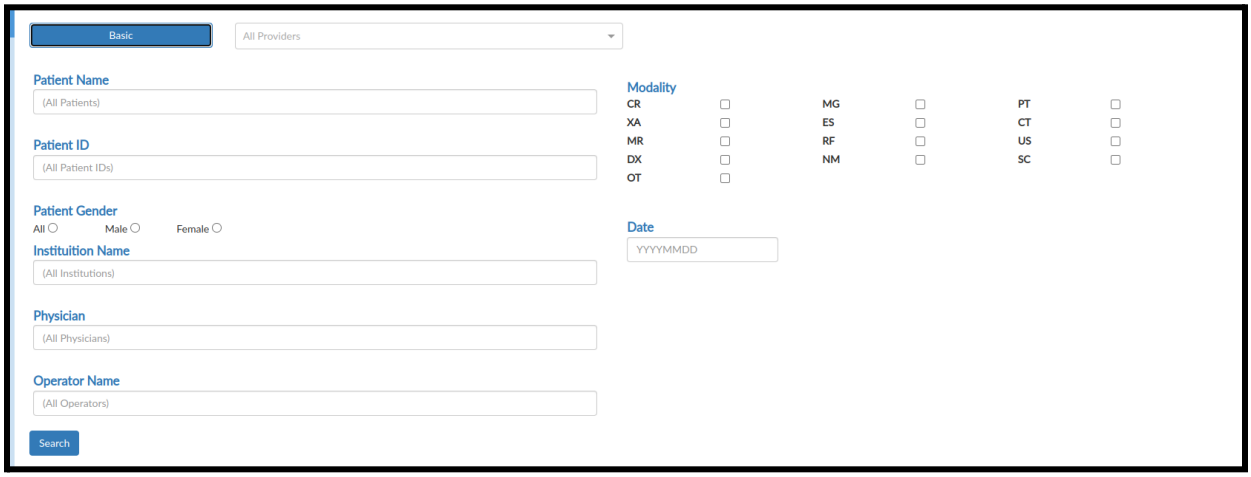

Figure 3: Dicoogle User Interface Showing the Basic Search Interface

The Dicoogle installation was configured to use the Lucene and File Storage prerequisite plugins, for facilitating indexing and querying of DICOM file metadata and storage of DICOM files, respectively (Dicoogle Team, n.d.). In addition, the native filesystem was used as the storage provider for storing and reading DICOM files.

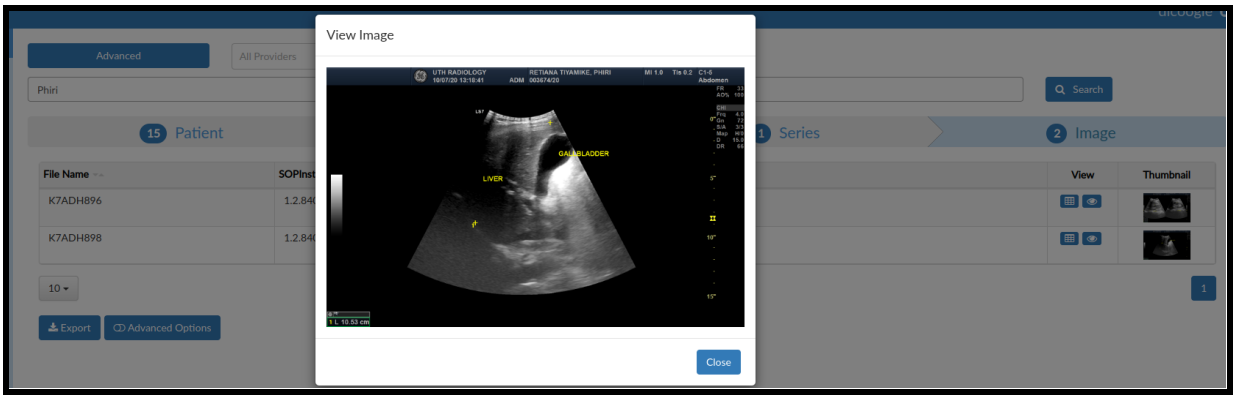

Figure 4: Dicoogle User Interface Showing a Thumbnail View of an Ultrasound Medical Image

Dicoogle is Web-based, with the user interface consisting of a management module and a public end user interface. The management module was used to configure network storage server locations, indexing options and auxiliary plugins integrated with Dicoogle.

DICOM images are discoverable using open ended searching, with faceted browsing for more focused searching. In addition, the advanced searching option, shown in Figure 3, enables users to specify parameters corresponding to DICOM files of interest. In addition, previewing of DICOM images, using thumbnails, is possible, as shown in Figure 4.

## 5. Conclusion and Future Work

This paper outlined how PACS platforms can be leveraged to facilitate effective Radiological workflows. In order to motivate why a PACS platform would potentially be beneficial in public health facilities in Zambia, a retrospective study was conducted, as outlined in Sections 3.1 and 4.1, focused on understanding how Medical Images are currently stored and accessed. A prototype PACS platform was subsequently set up and configured, as described in Sections 3.2 and 4.2, in order to demonstrate the feasibility of setting up a PACS platform.

Current studies, building up on ideas presented in this paper, are focused towards gathering a comprehensive set of requirements, specific to the Zambian context using a user-centred approach (Gulliksen et al., 2005). In particular, there is a need to identify varying ways that eventual users of the PACS platforms would ultimately search and browse for information. In addition, works are underway to evaluate the use of PACS platforms in a real-world environment. Furthermore, there is a need to determine how the PACS server could be integrated with a RIS platform such that interpretation reports are easily linked to Medical images.

The increase in the types of modalities used to generate Medical Images, and corresponding exponential growth of imaging requests, it becomes necessary to take advantage of the many opportunities presented by technological advances In the case of PACS platforms, the obvious benefits are in the form of increased efficiency and effectiveness at the point of care.

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