Enterprise Medical Imaging in the Global South: Challenges and Opportunities

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Abstract: The Republic of Zambia, like many other developing countries world-over, is faced with a critical shortage of trained radiologists—medical experts specialised in the interpretation and use of medical imaging for radiological diagnosis and treatment of health conditions. Coupled with the shortage of medical imaging experts is the limited use of modern medical imaging practices that facilitate efficient and effective interpretation of medical images. A potential solution for addressing these challenges is the implementation of Enterprise Imaging (EI)—techniques and workflows for acquiring, indexing, managing, storing and analysing clinical images, in order to enhance electronic health records. Implementation of a successful EI strategy has the potential to facilitate efficient and effective medical image interpretation, subsequently improving clinical care. The results from this study, through the analysis of the 2019 radiology annual returns report, indicates that General Radiography and Ultrasound were the most performed modalities. In addition, the current workflows and practices at UTH-Adult hospital Radiology department are monotonous with multiple interrelated challenges. Furthermore, there are unique EI implementation challenges, specific to Zambia, in addition to challenges highlighted in literature.

Keywords: Enterprise Imaging, Medical Imaging, Radiology, SWOT Analysis, Zambia.

1. Introduction

Pivotal to the holistic provision of clinical care is an efficient and effective clinical imaging service. Enterprise Imaging (EI) is designed to be the pivotal common clinical imaging resource that addresses the unique imaging needs for the multidisciplinary clinical care teams. In developing countries, however, two fundamental challenges stand out as hindrances to the efficient and effective use of imaging in care provision - critical shortage of Radiologists and the low utilisation of modern medical imaging practices that facilitate the efficient and effective interpretation of medical images.

Although the shortage of trained Radiologists is a global challenge, the situation is especially critical in developing countries. In Africa, there are an average of 3.6 Radiologists per one million of the population [1], compared to an average of 120 Radiologists per one million of population in Europe and the United States of America. It is reported that, as of the year 2020, only 9 trained Radiologists practiced in the public sector in Zambia against a population of 18 million [2]. By extrapolation, this figure translates to 0.7 Radiologists for every one million of Zambia's 12,600,000 (seventy percent) population that relies on public healthcare. On the other hand, the recent past has witnessed the emergence and increasing deployment of new advanced imaging equipment with high

performance capabilities, able to conduct by far more examinations in a given time period. These advanced imaging equipment in modalities such as Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) have inevitably led to a higher volume of radiological images that need to be effectively stored, processed and retrieved. In contrast, however, there is underutilisation of effective modern medical imaging practices, such as EI strategies. The low utilisation of the more efficient and effective modern medical imaging practices is multifaceted, among which are (but not restricted to) the perceived high cost, under-developed health care systems, lack of expertise among users and a lack of ability to deliver the high-technology infrastructure required. These challenges necessitate the use of effective solutions, such as the application of EI strategies, in order that imaging effectively supports quality healthcare delivery.

This paper focuses on presenting the grand challenges that adversely affect the effective interpretation of medical images and explores the opportunities that are available, within the existing limitations, for potential leveraging of EI strategies in order to enhance medical imaging interpretation in Zambia. The remainder of the paper is organised as follows: Section 2 presents existing literature that is related to this paper, while Section 3 outlines the research approach associated with this work. In Section 4, the radiological landscape in Zambia is presented, focusing on challenges observed by the researchers at the highest referral hospitals in Zambia - The University Teaching Hospitals. In Section 5, potential opportunities associated with EI are outlined and, finally, Section 6 discusses the conclusion and potential future directions.

2. Related Work

2.1. Radiology and Radiography Challenges in Zambia

Radiology and Radiography workers in Zambia include Radiologists, Radiology Nurses, Sonographers, Radiographers, Radiography Technologists, Dark room attendants, Medical Physicists, Radiation therapists and Nuclear Physicians. The challenge of low staffing levels in all these radiology workers has been well-documented in previous works, with the shortage said to be critical among Specialist Radiologists, Radiology Nurses, Nuclear Physicians and Medical Physicists [3]–[5]. This literature, however, has not reported the impact of this challenge and has not explored other challenges that include partially digitised imaging systems, increased workload, inefficient workflows, image storage and retrieval issues, disjointed departmental imaging services and limited expansion of the imaging sector beyond diagnostic services. Clinical imaging ought to integrate diagnostic and non-diagnostic imaging aspects such as Procedural Imaging, Evidence Imaging and Image-Based Clinical Reports [6] in order to provide a seamless service across the multidisciplinary clinical stakeholders.

2.2. Enterprise Medical Imaging

EI is defined as a combination of techniques, processes and procedures for facilitating the effective collection, storage, management, distribution and analysis of clinical medical imaging content in health settings [6]. In essence the purpose of an EI infrastructure is to ensure the effective integration of technological components involved in the end-to-end medical imaging workflows. Petersilge states that in addition to consolidating radiological infrastructure and services, EI provides an avenue for accommodating other forms of medical media [7]. Petersilge further states that EI has the potential to improve clinical care and operational efficiency. The increase in imaging modalities and, therefore, imaging

examinations, and the importance of reduced turnaround time of medical image interpretation reports necessitate the need for an effective EI strategy.

While the technological infrastructure is crucial for successful implementation of EI, Roth et al. propose that seven key elements are necessary for the successful implementation of an end-to-end EI program: effective governance, a clear EI strategic plan, a standards-based EI technological infrastructure, clinical images and multimedia content to be used by stakeholders, an enterprise image viewer for accessing and managing medical images, interoperable services capable of facilitating exchange of images with external services and, image analytics tools for reporting purposes [6]. However, implementation of EI strategies is not without challenges. Clunie et al. discuss key technical challenges and potential solutions associated with implementation of EI, primarily focusing on acquisition and management of enterprise images [8]. In order to highlight the significance of EI workflows, Towbin et al. describe workflow challenges and solutions that are aligned with EI [9]. It is worth noting that EI, similar to most technologically inclined undertakings, encompasses numerous aspects that involve key aspects of information systems: hardware, software, communications infrastructure, data sources, people and procedures [10], all of which need to be taken into account during implementation of an EI strategy.

Due to the complex nature of EI, careful planning is required for its successful implementation. Primo et al. recommend a 10-point plan for addressing core benefits and requirements for an institutional EI strategy [11].

3. Methodology

The primary goal of this work was to highlight the challenges and opportunities associated with the implementation and adoption of EI. A Strengths-Weaknesses-Opportunities-Threats (SWOT) analysis [12] was conducted—using the University Teaching Hospitals' (UTHs) Adult Hospital, in Zambia as a case study—in order to uncover the strengths, weaknesses, opportunities and threats associated with the implementation of EI. The weaknesses and threats are discussed in Section 4, while the strengths and opportunities are outlined in Section 5. The UTHs Adult Hospital was used as a case example as one of the authors has been actively practicing and working as a Radiology Resident in the environment, and as such has gained a unique perspective of the workflows associated with medical imaging interpretation and services.

The primary sources of data used in this paper include participant observations [13] conducted by one of the authors, working at the UTHs Adult Hospital; secondary data compiled by the Chief Radiographer—specifically, reported medical imaging examinations conducted in 2019—and, additionally, a meta-analysis [14] conducted to consolidate state-of-the-art work on EI.

3.1. Participant Observations

The participant observations conducted primarily involved identification of challenges and opportunities associated with the end-to-end radiological workflows initiated by the referring physician when they request for an imaging examination to be performed and interpreted, to the point when radiologists analyse and interpret the medical images and subsequently produce a detailed report.

3.2. Enterprise Imaging Meta-analysis

A literature review was conducted to consolidate prior work on EI. While there is a large body of literature on EI, the focus was on work by the Society for Imaging Informatics in Medicine (SIIM)[1]. Specifically, the literature surveyed was restricted to work highlighting challenges associated with implementation of EI and literature that focused on strategies and implementation guidelines.

3.3. SWOT Analysis

As earlier stated, data analysis was conducted using a detailed SWOT analysis that was aimed at identifying challenges and opportunities. A SWOT analysis was chosen as a methodology for analysing potential challenges and opportunities due to its proven effectiveness when formulating organisational strategies [15] and because of its increasingly wide application in academic research [16].

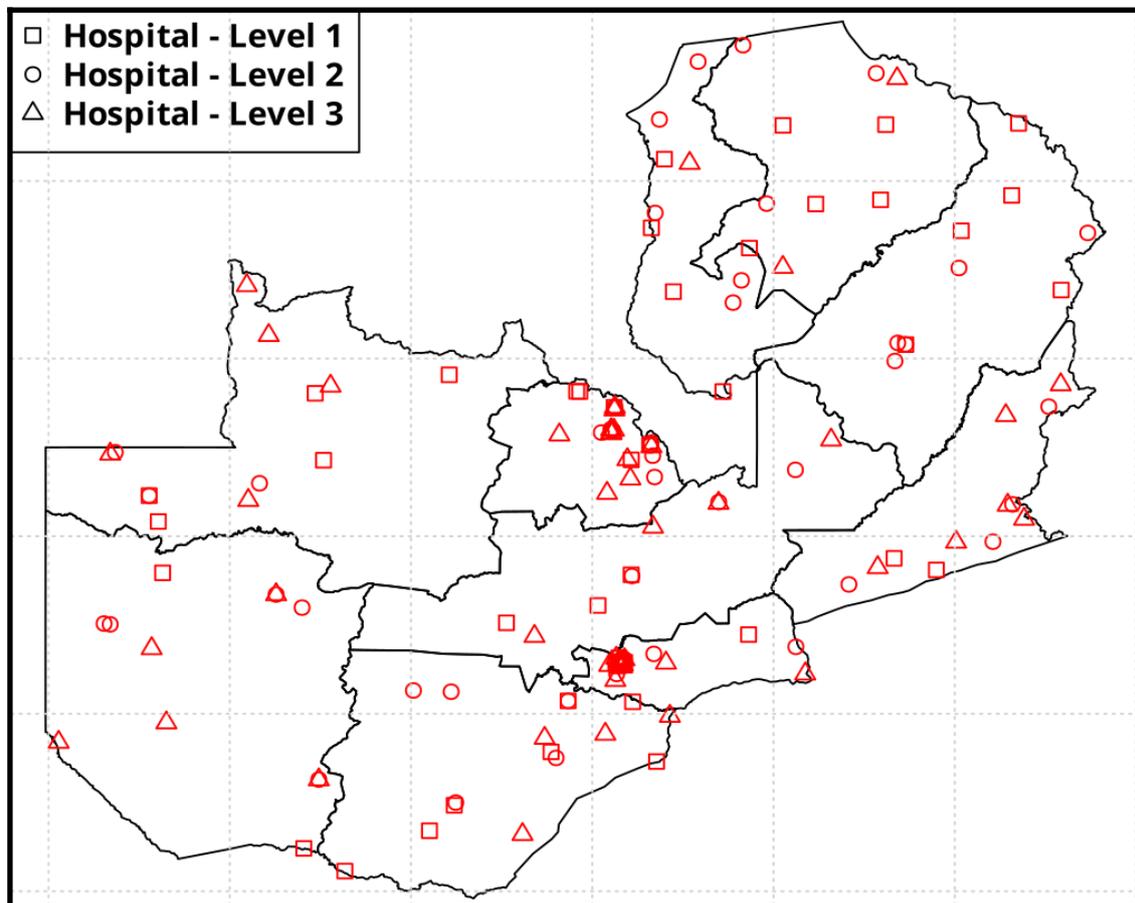# 4. Radiological Landscape in Zambia

Figure 1: Distribution of Level 1, 2 and 3 Health Facilities in Zambia

The hierarchy of the Zambian healthcare system has the Health Post as the lowest point of care, followed by the Urban/Rural Health Centre. The next three levels of care are referral facilities designated Level 1, Level 2, and Level 3 hospitals according to the catchment population, inpatient bed capacity and specialist care provided.

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1 https://siim.org

Radiology services in Zambia are mainly provided at referral facilities (Level 1 to Level 3 Hospitals), although a selection of health centres offer some basic imaging services. The majority of facilities providing radiological services are run by the government through the Ministry of Health (MoH). Others include the Defence Force Medical Services, missionary or non-governmental organisations and the private sector. Figure 1 shows the distribution of health facilities in Zambia's 10 provincial regions [17].

The higher the facility is within the health system hierarchy, the higher the radiology equipment and staff establishment. Thus, Level 3 Hospitals generally have more diverse imaging modalities. The most widely accessible modalities and therefore the most frequently performed as shown in the example for UTH-Adult Hospital in Figure 2, are General Radiography (GR) and Ultrasound (US), which are accessible almost invariably at all facilities that offer imaging services. Higher facilities may additionally have one or more of the following modalities: Fluoroscopy (FL), Mammography (MM), Dual-Energy X-ray Absorptiometry (DEXA), CT, Digital Subtraction Angiography (DSA), MRI and Radioisotope imaging. The Radiation Protection Authority (RPA), is mandated and responsible for licensure and maintenance of a comprehensive inventory of the country's registered medical imaging equipment as well as regulating medical radiation practices.
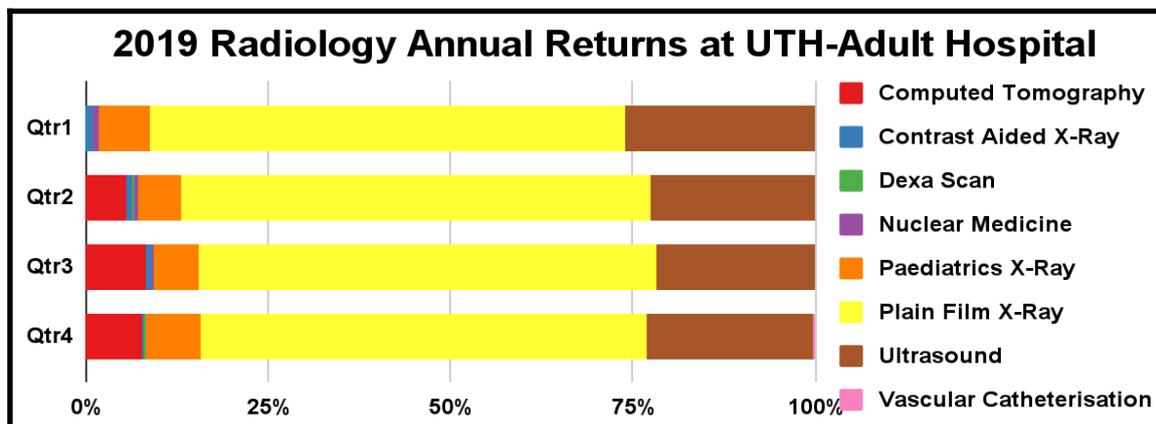

Figure 2: 2019 Radiology Annual Returns at UTH-Adult Hospital

4.1. Imaging Workflows Case Example: University Teaching Hospitals in Zambia

The University Teaching Hospitals (UTHs)[2] consists of five separate, specialised but co-located hospitals which are the highest referral healthcare facilities in Zambia with superspecialist services. While some sister hospitals within the UTHs have some imaging suites, the main Radiology department falls under the Adult Hospital.

Although minor differences in the individual steps through the imaging process may exist between facilities and facility levels, the general workflow given here for UTH-Adult hospital Radiology department is generally accepted as being similar in most facilities.

The process to perform an imaging examination in any modality is initiated when a physician refers a patient or client through a filled-in request form to conduct an examination, or when the radiologist recommends a follow-up examination based on findings from a previous examination. The request form bears the patient's demographic details, requesting physician's identity and contacts, relevant clinical history, indication for imaging examination and the specific examination being requested. In the Imaging

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2 http://www.uth.gov.zm

Department, the patient is manually scheduled for the examination by a Radiographer according to the next available date, most often without prior verification of the information on the request form by the Radiologist. At the beginning of the procedure/examination, the patient's demographic details and examination type are entered. The images acquired during the examination are kept for a variable length of time, pending reading, either in the form of a printed cassette film or digitally saved on a compact disc. When finally other factors at play allow, the images are presented to a qualified or in-training radiologist for reading, a process which also takes variable time depending on the complexity of the findings and who the reader is and whether they require a consultant's authentication of the report before it is issued out. Following a thorough analysis and interpretation of the images, the interpreter generates, types and prints a report stating the salient findings and conclusions. Ultrasound modalities, on the other hand, take a slightly different path, with image acquisition and analysis performed simultaneously and usually ends with an immediate issuance of a handwritten report. As a result, with the exception of Ultrasound modalities where the report is issued within minutes after the examination, most other modalities take variable times ranging from hours to months for the report to be issued. The report is issued to the patient, physician or third party, who is alerted through a non-automatically generated cell phone message. The images (analogue or digital) are surrendered along with the report. For digital images, however, copies that are retained on the imaging equipment saver are backed up on compact discs or external hard drives. It is not uncommon for finished reports to remain uncollected despite sending messages calling for their collection, resulting in a hold-up of completed reports within the department.

4.2. Radiological Workflow Challenges

The current workflows and practices at UTH-Adult hospital Radiology department are monotonous with multiple interrelated challenges:
- Inadequate request forms: incompletely filled-in or ineligible request forms with no physician contact details for clarification, making the justification for imaging difficult and hindering selection of optimal imaging modality options
- Unverified request forms: this is due to non-availability of a radiologist to scrutinise the justification or relevance of the examination requested, leading to unnecessary examinations and in some instances, unnecessary radiation exposure to the patient
- Redundant and repetitive steps: repeated manual capturing of patient data at examination scheduling, imaging and reporting, making the process unduly long
- Increased examination rejects and repeats: this results from the continued use of analogue technology in some modalities such as GR and MM, and lost or spoilt examination images due to prolonged waiting times and handling. This adversely increases the patient radiation exposure and/or stay within the department
- Long patient waiting times: due to increased number of patients resulting from increased demand for imaging and long traditional radiology workflow activities
- Increased workload: is as a result of the disparity in the rate at which examinations are performed and the rate at which the examinations are concluded, leading to a pile-up effect at the reporting stage
- Difficult retrieval of historical images and reports: due to non-systematic storage of images and reports, retrieval of these is difficult. Historical Images and reports are a necessity in follow-up examinations for comparative analysis of disease interval changes, in post-treatment cases for determination of disease recurrence, in

postoperative cases for assessment of residual disease as well as in postoperative assessment of acceptability of corrective procedures

- Long report turnaround time: the UTHs have only two qualified Radiologists against a large volume of imaging examinations as exemplified in Figure 2—for instance, in 2019, there were a reported 92,593 medical imaging examinations in various modalities requiring interpretation. The consequence of long report turnaround time is that, salient findings with the potential to influence or completely change the patient management plan are communicated late, thereby jeopardising the potential good patient outcome
- Uncollected reports: as earlier stated, this is as a result of lack of, or use of ineffective communication strategies

4.3. Enterprise Imaging Implementation Challenges

Clunie et al. explored the technical challenges of acquiring and managing enterprise images that involve visible light and further proposed solutions to the identified challenges [8]. In addition, Towbin et al. identified crucial EI workflow challenges and solutions that have the potential to hinder successful implementation of EI strategies [9]. It is also widely acknowledged in literature that substantial cost and ongoing investment, requirement for good Information and Communication Technology (ICT) support service, training of users and requirement for a good understanding of complexities involved in EI implementation are the major challenges facing EI implementation in the global south [18].
While these challenges are equally applicable to the Zambian situation, unique challenges are also identified:

- Lack of interfaced Picture Archiving and Communication System (PACS), Radiology Information System (RIS) and Hospital Information System (HIS) platforms: the greater majority of facilities and institutions lack these organised systems, significant requirements for a functional EI platform
- Use of analogue modalities: the persistent use of non-DICOM compatible systems mainly in GR, MM and FL may entail exclusion of some of the most frequently performed examinations, rendering EI implementation pointless
- Poor infrastructure and lack of consistent equipment maintenance: lack of good ICT infrastructure and old, poorly-serviced radiology equipment with frequent and long downtimes can hamper implementation of EI
- Inconsistent Internet connectivity: this may affect the effectiveness of the Teleradiology, a key element of EI that is extremely important in the current setting of a crucial shortage of radiologists
- Parallel imaging service lines: although relatively well-established in their respective departments, the imaging sections of the different departments are currently operating independently

5. Opportunities

In this section, opportunities that can potentially result in the successful implementation of an EI strategy in Zambia are outlined, by referring to the key elements, proposed by Roth et al. [6], encompassing a successful EI program.

5.1. Governance and Strategy

There are pre-existing administrative and technical structures within the departments that incorporate some form of clinical imaging, including Diagnostic Radiology, Endoscopy,

Cardiology, Dermatology, Ophthalmology and Pathology. An EI platform would leverage the long-term experience gained by experts in the running of the respective imaging sections to form a competent EI governing body.

In addition, there is an Electronic Health Record (EHR) framework in place that has seen the SmartCare EHR platform being rolled out in health facilities country-wide [19]. The existing EHR framework would make it possible for EI governance and strategies to be easily devised.

5.2. Medical Imaging Content and Technological Infrastructure

One of the major strengths of the existing ecosystem at UTHs and indeed Level 1, 2 and 3 hospitals is that there exists equipment used to produce medical images in the various modalities. While the medical images produced in these modalities are presently archived on CDs, the implementation of a PACS platform would make it possible for medical images to be archived in a scalable and easily searchable platform.

In addition, while manual, there are workflows in place that could potentially be incorporated into an EI-centric ecosystem. The existing manual workflows could potentially be integrated into the SmartCare EHR workflow in order to ensure seamless exchange of data between EI platforms and the SmartCare platform. Furthermore, although not currently operational, there is a pre-existing interconnectivity linking some provincial general hospitals to the UTHs over which digital images can be shared.

Due to the lack of availability of a PACS platform, performing analytics on historical data, in order to identify trends, is problematic. The implementation of an EI ecosystem would make historical data easily accessible, making it possible to not only analyse historical data, but also implement predictive models.

6. Conclusions

In this paper, challenges and opportunities of implementing successful EI strategies were presented, using the UTHs Adult Hospital in Zambia as a case example. The challenges and opportunities were arrived at using findings from participant observations conducted by one of the authors, secondary data compiled from medical imaging reports and a literature review of the broader EI landscape. The shortage of Radiologists and the low utilisation of modern efficient and effective medical imaging strategies, such as EI, provide the motivation for the implementation of EI strategies in developing countries. The implementation of the EI strategies offer a number of potential benefits for addressing the challenges identified, through the use of effective medical imaging workflows. EI can arguably result in the drastic reduction of operational costs through the automation of workflows and, most significantly, enabling the improved efficiency of the workflows, subsequently improving patient and clinical stakeholder satisfaction. This work is set to potentially stimulate a drive, among stakeholders, towards consideration and subsequent adoption of EI strategies for improved radiological image interpretation practices in Zambia and the general global south.

6.1. Future Work

The implementation of a successful EI involves a number of unexplored areas, most of which can be realised through future work. In order to comprehensively understand the Radiological landscape in Zambia and fully understand how an EI strategy could be effectively used, current research being conducted includes exploratory studies aimed at

understanding workflows used by key stakeholders in health facilities across Zambia. There are also ongoing plans to implement and deploy PACS and RIS platforms, to aid in timely and effective reporting. In addition, prototype machine learning models are being developed in order to demonstrate the potential benefits of EI platforms in making Radiologists more efficient and effective. Further research could explore automatic generation of reports, which are presently manually prepared.

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