A TECHNICAL, FINANCIAL AND CLINICAL COST BENEFIT ANALYSIS OF INTEGRATING A DICOM BASED PACS AT THE KIGALI UNIVERSITY TEACHING HOSPITAL

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PG 2011/636

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March, 2015

DECLARATION

I declare that this Dissertation contains my own work except where specifically acknowledged

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Signed:

Date: 13th March 2015

DECLARATION OF THE AUTHORITY TO SUBMIT THE THESIS

I, **Dr Jean Paul NIYOYITA**,

In my capacity as a supervisor, I do hereby authorize MARARA Alpha-Arsene to submit his final thesis.

Date: 16th, March, 2015

Dr NIYOYITA Jean Paul

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I thank the Almighty God who granted me good health, kept me safe for the whole duration of my postgraduate studies.

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GOD BLESS YOU!

ABSTRACT

This study aimed at providing a technical, clinical and financial cost benefit analysis of the integration of DICOM based PACS at Kigali University Teaching Hospital (CHUK). CHUK's radiology department is a busy department which is enduring chronic difficulties related to the management of the radiology department activities, low productivity, and poor quality of radiology service delivery and so on.

The overall objective was to develop a solid understanding of the clinical, financial and technical costs and benefits of integrating a DICOM based PACS at Kigali University Teaching Hospital thereby taking into account the improvement of the quality and productivity of health care service delivery. A retrospective, descriptive and analytic design guided the study. A random sampling strategy was used to select the unit of the study. A quantitative and qualitative method was used to analyze data. A questionnaire, activity and financial reports were used to collect the data. The study has a hypothesis saying that "The integration of DICOM based PACS is clinically, technically and financially beneficial to CHUK."

Convincing evidence has been collected relating to present clinical, financial and technical problems and risks before integration of DICOM based PACS at CHUK. Some of the results were presented in tables, others in figures and later discussed. The results found revealed clinical, financial and technical problems encountered in the radiology department's daily activities. On the other hand, this study revealed an avoidable number of clinical, financial and technical factors causing cost of loss and also affecting the radiology department productivity and healthcare service delivery. However indications have been provided that DICOM/PACS integration interfaced with other information technology systems could also achieve a number of financial challenges related to the expensive cost of x-ray films and consumables, cost of lost x-ray film results before medical ward round, cost of duplicated x-ray images, cost of erroneous prints of x-ray film results, unbilled performed x-ray imaging procedures, disposal of radiology waste materials and paper based request forms for x-ray exams. In this study, evidence confirming the hypothesis saying was given.

At the end of the study, the recommendations were addressed to the ministry of health, the Kigali University teaching hospital and other researchers.

KEY WORDS

PACS, integration of DICOM/PACS, modalities medical x-ray images, radiology, time duration.

LIST OF SYMBOLS AND ABBREVIATIONS/ACRONYMS

ACM: Association for Computing Machinery

ACR: American College of Radiology

bpp: bits per pixel

C: Compliant

CD: Compact Disk

CHU: Centre Hospitalier Universitaire

CHUK: Centre Hospitalier Universitaire de Kigali (Kigali University Teaching Hospital, in English)

CR: Computer Radiography

CT: Computer Tomography

DICOM: Digital Imaging and Communication in Medicine

EHR: Electronic Health Record

ENDO: Endoscopy

F-Y: Fiscal Year

G-O: Gynecology and Obstetrics

HIS: Hospital Information System

HL7: High Level Seven

IEE; Institute of Electrical and Electronics Engineers

IM: Internal Medicine

ISO: International Standards Organization

IT: Information Technology

JPEG: Joint Photographic Expert Group

LAN: Local Area Network

MIFOTRA: Ministère de Formation et du Travail

Min.: minute

MOH: Ministry Of Health

N/C: Non Compliant

PACS: Picture Archiving Communication System

RIS: Radiology Information System

FRW: Franc Rwandais

TCP/IP: Transmission Control Protocol/Internet Protocol

US$: United States Dollar

US: Ultrasounds

USA: United States of America

WAN: Wide Area Network

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DEDICATION

I dedicate this dissertation:

To Almighty God,

To my late mother

To my father

To my wife

To my brothers and sisters

To my supervisor, Dr NIYOYITA Jean Paul

To my co-supervisor, Mr. Gustave KARARA

To my place of work: CHUK

CHAPTER 1. INTRODUCTION

Long ago up to present, in radiology department, the typical means of taking, recording, reporting, storing, retrieving or viewing medical x-ray images were film and paper based hard copies. However, advances in technology introduced DICOM, PACS and HL7 interfaced with information technology systems into radiology imaging technology in order to completely replace film-based radiology services within the hospital. Numerous technical, clinical and financial cost benefits are given to explain why the integration of DICOM based PACS could be profitable to Kigali University Teaching Hospital (CHUK).

This chapter covers the background of the study, definition of key terms, statement of the problem, objectives, research questions, significance and the subdivision of the study. This thesis examines various topics related to clinical, financial, financial cost benefits of DICOM and PACS integration in a hospital.

1.1. Definitions of key terms

Bit per pixel (bpp) is defined as "the number of bits used to define the grayscale value or color value of a pixel. E.g.: Modern color systems often have 24 bits per pixel giving 256 possible values for each of the red, green, and blue components" (62).

Digital Imaging and Communication in Medicine (DICOM): "is defined as the standard used for the electronic transferring of digital image data, developed by a joint committee of the American College of Radiology and the National Electronics Manufacturers Association." (Mosby's Medical dictionary, 2009)

Electronic Health Record (EHR): "is a longitudinal electronic record of patient health information generated by one or more encounters in any care delivery setting. It automates and streamlines the clinician's workflow. Included in the generated patient health information are patients demographics, progress notes, medications, vital signs, past medical history, immunizations, laboratory data and radiology report etc" (32).

HIS: short for Health Information System, it is designed for use in healthcare facilities to manage the medical, administrative, financial and legal aspects of a hospital.

Health Level Seven (HL7): is a standard for exchanging or transmitting health-related information between medical applications which is sent as a collection of one or more messages. It is useful for healthcare data flows.

Interoperability: "The condition achieved among communications-electronics systems or items of communications-electronics equipment when information or services can be exchanged directly and satisfactorily between them and/or their users. The degree of interoperability should be defined when referring to specific cases"(55).

Joint Photographic Expert Group (JPEG): "is defined as a lossy compression technique for images. Although it can reduce files sizes of their normal size, some detail is also lost in the compression**"** (33).

Network connectivity: "describes the extensive process of connecting various parts of a network to one another, for example, through the use of routers, switches and gateways" (54).

Picture Archiving Communication System (PACS): can be defined as a network of computers used by radiology departments that replaces film with electronically stored and displayed digital images. It provides archives for storage of multimodality images, integrates images, and displays both images and patient information at work stations throughout the network. It also allows viewing of images in remote locations" (Mosby's Medical dictionary, 2009) (3).

RIS: Short for Radiology Information System, RIS is "a computerized database used by radiology department to store, manipulate and distribute patient radiological data and imagery. The system consists of patient tracking and scheduling, result reporting and image tracking capabilities"(34).

Referral hospital (also called tertiary referral hospital)**:** means a hospital which has highly specialized clinical staff and services differentiated by function, and specialized imaging units; could have teaching activities; size ranges from 300 to 1,500 beds (56).

Workflow: "A series of tasks to produce a desired outcome, usually involving multiple participants and several stages in an organization. It includes the procedures, people and tools involved in each step of a business process"(53).

X-ray: "is a type of electromagnetic radiation, just like visible light" (57).

2K resolution is define as "a generic term for display devices or content having horizontal resolution on the order of 2,000 pixels. E.g.: The resolution of an image formed of 2048 pixels per line and 1080 pixels per column, or about 2 million pixels per image" (63).

1.2. Background to the study

Standards are important and necessary to improve the exchange of health information and medical image data, expected to result in improved quality and efficiency of patient care and radiology productivity. In developed countries, the explosive growth in imaging size and complexity (e.g. CT scan) has driven the need of digital image management, and gave rise to issues of storage space and costs, and in the same way, has sparked a challenge for increasing or getting an adequate speed for transmitting, accessing and retrieving medical image data (1).

However, the issues of acquiring image information from medical imaging devices, the search for a suitable digital image management format for storing, accessing and retrieving medical image data without loss of information and medico-legal implications as well as the cost reduction constitute a necessity and subject of emergency. The existing standards like Digital Imaging Communication in Medicine (DICOM) and Picture Archiving and Communication System (PACS) are associated with other standards and information systems such as Health Level Seven (HL7), JPEG, Hospital Information System (HIS) or/and Radiology Information System (RIS) to communicate all of the information necessary to permit the receiving system to completely utilize the images (2).

DICOM is an information system and is also a standard for handling, storing, printing and transmitting information in medical imaging. Its files can be exchanged between two entities capable of receiving medical image and patient data in DICOM format. It allows the integration of scanners, servers, workstations, printers, and network hardware from multiple manufacturers into a picture archiving and communication system also called in short PACS (2).

In many developed countries, the digital imaging in radiology departments is developed. A majority of radiology departments have now become filmless with interpretation done on pictures archived in PACS where they are stored for future use (51). Developing countries do not have access to filmless digital imaging enjoyed by the developed countries, and some of the mounting health crisis in developing countries is related in part to the lack of adequate integration of information systems in radiology (51).

In health care settings owning a radiology department, the transition to the acquisition of DICOM and PACS lighted a high-quality of clinical services delivery, economic benefits and high productivity. Such integration enables clinicians to interoperate with each other, to access both electronic patient data with digital images reliably and consistently in their regular working environment. This eliminates the need to manually file, retrieve, transport or buy film jackets and to wait for the medical image results.

1.2.1. Issues in digital radiology management

Radiology can be normally considered as part of the service industry which includes customer service, customer satisfaction as well as all issues related to healthcare quality improvement.

When looking at the limitations in the acquisition of PACS combined with DICOM standards in digital radiology management, we necessitate to understanding DICOM/PACS integration's cost benefits related to the workflow and healthcare delivery efficiency, time saving, administrative cost benefits, productivity, costs effectiveness and total expenses over a full lifecycle of an investment.

In radiology department, such problems of handling large volumes of images, ownership of data, data exchange, printing of films, patients' data security, lack of an efficient workflow, supporting a billing system based on imaging performed procedure, improving radiology staff productivity, quick access of patient's image results, management of costly maintenance of printers are presented as important chief complaints from radiology staff and clinical staff.

At this point, there is an essential need to address radiology department's daily challenges by introducing technology advances in order to improve service delivery and customer satisfaction. It is expected that integration of ubiquitous computing technology with DICOM associated to PACS and also joined to hospital information systems like Electronic Health Record (EHR) and/or Radiology Information System will support the medical imaging workflow within the hospital and improve the productivity of the radiology department.

1.2.2. DICOM and PACS workflow scenario

The integration of DICOM based PACS can be very advantageous on the clinical, technical and financial side. It facilitates an efficient and effective workflow within or between healthcare settings.

Example regarding with DICOM and PACS workflow scenario indicates in three important parts that modality medical x-ray exam orders from wards are entered into the Hospital Information System. The patient information along with the scheduled modality medical x-ray study information is transferred to radiology department server via RIS/HL7. The scheduled modality medical x-ray study information becomes available to the medical x-ray modality via the DICOM of modality work list service. At this level the patient and study data are entered once so that it removes the possibility of errors.

The radiology technician brings the patient into the exam room, chooses the ordered modality medical x-ray procedure from the work list and performs the exam. Once the imaging is complete, the modality medical x-ray images are automatically sent to PACS Server. At that point, the completed modality medical x-ray exam automatically appears on the radiology technologist's work list. The radiology technician inspects, verifies the images and demographics, and adds any required notes. As soon as he completes this work, the modality medical x-ray exam moves off of their work list and is ready for radiologist interpretation.

When a radiologist who was not present is back, he logs in PACS; then he automatically sees all unread exams. For read exams that have been interpreted by the radiologist with a single report, they disappear from the unread work list and immediately become available to report transcription or recording. The reports are then sent back into PACS Server via HL7 and are automatically associated with the images, allowing them to be easily accessible for prior study comparison. And via DICOM, interpreted or reported modality medical x-ray study reach hospital physicians who will use the EMR to view reported modality medical x-ray images results on their workstations.

Or, if a patient decides to switch hospitals, and the new hospital produces its medical images from a different vendor, then there would be a difficulty in safely transferring any previous medical image data from CT's or any kind of radiology images to the new hospital. With the

DICOM standard based PACS, this is not an issue. Technically, systems like workstations, intra oral cameras, ECG, imaging systems, digital radiography systems, and different modalities like CT scanners, ultrasound systems made by different manifacturers located at one site or in many sites are ready to communicate with each other by using DICOM accross the system network. There is no need to print films because medical images can be captured and transferred electronically whenever physicians request them, providing an important financial benefit. Medical professionals can make their diagnosis and treatment for patients rapidily and retreive medical images data of patients for research purpose or specific information at anytime. A decrease of expenses (filmless) and time (reduction of staff turnaround time) result from it.

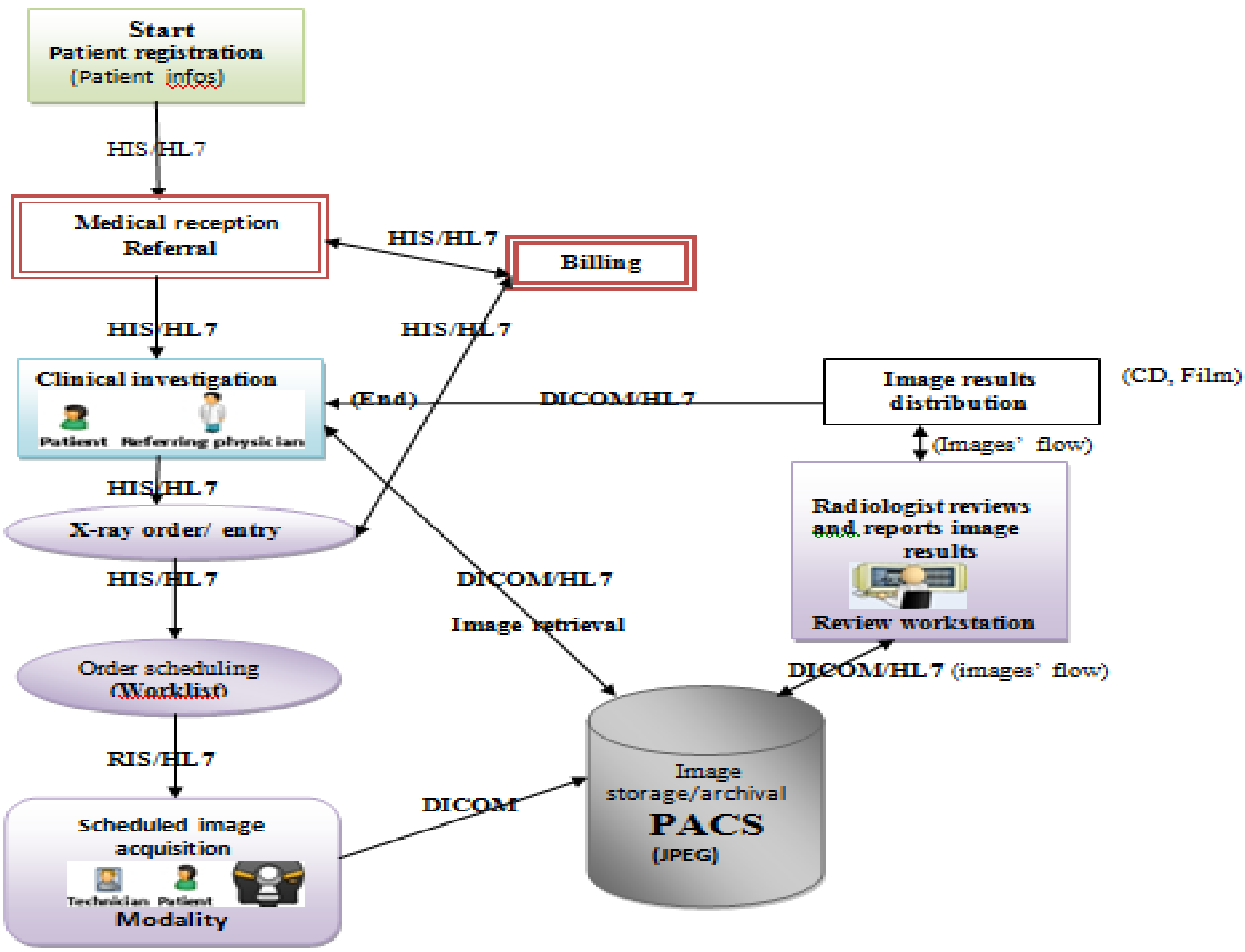

Figure 1.1: Example of radiology workflow by using DICOM/PACS interfaced with other information technology systems.

1.3. Problem statement

The present state of medical imaging in Rwanda is in majority based on film based manual systems involving plain radiographs. And in most cases, the medical images are generally interpreted or reported by health care providers (physicians or surgeons). The reporting by the consultant radiologists is carried out on demand only for special cases. All other medical images are produced without being reported. They are handed over to patients and further retrieved from them on subsequent medical visits.

In addition, CHUK is actually using a health information system (OpenClinic) for electronically recording patient data information, scheduling medical consultations, billing and managing laboratory results. The hospital owns about 200 workstations without mentioning the undetermined number of personal computers used by medical and nurse students, lecturers and so on. Although the hospital is using OpenClinic to handle all electronic patient records, a remaining big issue is the fact that the radiology department does not have a Radiology Information System. All radiology modalities are not online or networked and there are no servers which are usefull for storing, communicating, archiving, requesting and transferring medical imaging data.

Actually, the digital imaging system in CHUK generates a very high number of X-rays per day according to the technologist in charge. During working days, 70 to 100 plain radiographies are made per day and 20 to 30 CT scans. During weekends this is reduced to 20 to 30 plain radiographies and 3-5 CT-Scans. Few of these are reported by a consultant radiologist and a number of them are returned to the physicians without being reported at all. The whole radiology department has only two radiologists who are qualified to make reports or interpretations of x-ray results. Looking at their high workload, this is insufficient.

Based on the size of the hospital which owns 534 beds with a large offer of specialized medical departments (27), and on the efficient and rapid quality service delivery needed, the CHUK radiology department is working almost 24 hours a day. This operating schedule is associated with constraints of insufficient manpower, administrative costs, long film based printing processes (handling large volumes of images), timely reporting of medical images, patients' data security, quickly accessing patients' image results, generating medical imaging errors.

Moreover, CHUK handles huge number of patient referrals from district hospitals, clinics and private health centers; many of those referral cases are eligible to pass through the radiology department according to the clinical investigation conducted in their different respective hospitals. The average time spent on developing and reporting an x-ray or CT scan is longer than expected. The patient details are also difficult to retrieve by the radiologist through the EHR because the latter remains underused and the scheduling, registration, billing or tracking of patients is still paper based.

Doing so, the time required for the production and communication of medical image results to the applicants ranges from 12 hours to more than 36 hours from the time of prescription of a medical image exam by physician up to its availability. While we find in some research conducted in health care institutions which implemented the PACS/DICOM system that physicians spent less than 40 minutes waiting for results of medical image results since their prescription (25).

Another important issue is the loss of hard copies due to error and deterioration of medical image results. These medical images results that got lost or damaged are often reproduced, increasing the burden on an already cumbersome system.

The traditional film development is indeed expensive. For example: It includes printing of x-ray film, expensive consumables, used materials destruction, staffing, physical storage and transportation which are often considered as additional and inevitable costs. Therefore, we will analyze the clinical, technical, and financial cost benefits of integrating DICOM based PACS at CHUK.

1.3.1. Description of the radiology department

The radiology department is one of the busiest departments of CHUK. It has 3 radiologists, 8 radiology technicians, 2 nurses and 3 support staff. Some time ago, different partners including BTC helped to equip CHUK including the radiology department. Since then, it has a digital film based radiology department with 2 x-ray rooms (plain radiography), 1 fluoroscopy and mammography room, 1 computed tomography room, and 1 ultrasound room and 3 mobile general radiography machines for critically ill patients in the emergency department and the wards. The department has also 1 reception desk and 1 cash billing unit outside the department shared with the Accident and Emergency department. The imaging procedures performed in the radiology department are fluoroscopy, mammography, computed tomography (CT) and plain radiography (X-ray). In addition, there is also a medical ultrasound.

1.4. Objectives of the study

1.4.1. Main objective

The main objective is to investigate the clinical, financial and technical costs and advantages of integrating a DICOM based PACS at Kigali University Teaching Hospital (CHUK) and how it can improve the quality and productivity of health care delivery.

1.4.2. Specific objectives

The specific objectives are as follows:

1. To investigate present clinical, financial and technical problems and risks before integration of DICOM based PACS at CHUK;
2. To analyze the possible clinical benefits of integrating DICOM/PACS at CHUK;
3. To analyze technical advantages of acquiring DICOM/PACS at CHUK;
4. To analyze financial cost benefits of integrating DICOM/PACS at CHUK
5. To recommend actions encouraging an integration of DICOM based PACS.

1.5. Research question

“What is the cost- benefit of acquiring DICOM associated to PACS at CHUK?”

1.6. Hypothesis

“The integration of DICOM based PACS is clinically, technically and financially beneficial to CHUK.”

1.7. Significance of the study

This study is investigating on the clinical, financial and technical benefits of using DICOM based PACS in CHUK which is at a level of referral hospital. Research in this field can be used to provide solid information for hospital administrators and radiology department staff of Kigali University Teaching Hospital (CHUK) thereby taking into account the improvement of the quality and productivity of radiology department service delivery.

This study will also be beneficial by helping us to acquire practical skills and get the award of a Masters degree in Health Informatics. In addition, this research will be broadcasted in Kigali University Teaching Hospital (CHUK) in order to raise awareness of the benefits of DICOM based PACS standards integration in the healthcare settings. Recommendations will be made to CHUK to consider the DICOM based PACS integration.

There was currently no research available of this type from CHUK, and such a study will be a starting point for future research in this referral hospital setting.

1.8. Subdivision of the study

This study is divided into six chapters. The first chapter is a general introduction to the study, including the background, the problem statement, objectives of the study and the study hypothesis. The second chapter includes the literature review on the subject. It mainly defines the concepts of the study. The third chapter is devoted to the methodology for this research. The fourth chapter is focusing on the presentation of results. The fifth chapter is focusing on the discussion. Then, the sixth chapter of the study takes into account conclusions and different recommendations.

CHAPTER 2. LITERATURE REVIEW

As medical imaging becomes increasingly important to the delivery of effective healthcare, various new radiology technologies are required to manage, store and share complex medical x-ray images so that they can be accessed by any healthcare provider who needs to use them. These latter are also used for fast and cost effective access to medical x-ray images whenever and wherever they needed.

In this review, we discussed on the clinical, financial and technical cost benefits, role and advantages of DICOM/PACS integration in radiology.

2.1. Medical imaging modalities

First of all, the medical imaging used for healthcare purposes engages medical imaging modalities, services of radiographers, radiologists, physicians, radiology nurses and biomedical engineers working in concert as a team for improving quality healthcare service delivery.

Secondary, many reports have been published about the accuracy of various medical imaging modalities including: General radiography, Ultrasound, Computer tomography (CT), Mammography, Dental radiography, Fluoroscopy and other specialized medical imaging modalities in improving medical diagnostic decision making. The ability to capture, to print and view complex medical x-ray images are enabled by these medical imaging modalities (61).

Each imaging modality provides specific types of information regarding the morphology, physiology or metabolism composition within biological tissue and offers that information on a certain spatial and temporal scale. Some described examples of medical imaging modalities which can deal with DICOM and PACS include: **Computer tomography (CT scan)** which "uses x-rays to create three dimensional pictures of cross-sections of the body. This is especially useful for looking at soft tissue structures such as lungs, liver, colon Mammography" (58); **Dental radiography** which provides "a type of picture of the teeth and mouth and uses x-rays as a form of electromagnetic radiation, just like visible light" (60); **Mammography** which "uses x-rays to capture images (mammograms) of the internal structures of the breasts. Mammography can help detect breast cancer in its earliest, most treatable stages; when it is too small to be felt or detected by any other method" (59); **Fluoroscopy** which is " a type of medical imaging that shows a continuous x-ray image on a monitor, much like an x-ray movie. During a fluoroscopy procedure, an x-ray beam is passed through the body. The image is transmitted to a monitor so the movement of a body part or of an instrument or contrast agent through the body can be seen in detail" (59) and **General Radiography** which "uses an x-ray beam which is passed through the body. It is also used to diagnose or treat patients by recording images of the internal structure of the body to assess the presence or absence of disease, foreign objects, and structural damage or anomaly" (59).

Thirdly, to enable healthcare providers to make medical x-ray images accessible as well as written records and reports wherever they are needed, radiology standards such as DICOM, PACS and HL7 were developed to work together with medical imaging modalities. These radiology standards interfaced with the information technology systems such as HER or EMR may be expected to support medical imaging modalities to offer quality radiology service delivery.

2.2. Overview of DICOM/PACS

In developed countries, the cost-benefits of integrating standards are also apparent in medical imaging because those standards have enabled the present day medical imaging to be virtually free of printed film with remote and multiple accesses from electronic image integration platforms. Consequently, the radiology department workflow management thus achieved has contributed to improve quality and efficient health care in those nations (4).

In fact, the use of standards in digital imaging reduces medical systems overall cost and increases hospital efficiency. Digital medical imaging tends to be large in size and is network bandwidth demanding. The full annual volume of medical images in a modern hospital easily reaches 10 Terabytes (5). In addition, Picture Archive and Communication System (PACS) needs Gigabits of network bandwidth (6,7). For instance, a typical digital X-ray image can be a 2Kx2K grayscale image represented with 12bpp which lets understand that the medical image would almost be about 50 megabits(8). Image compression will help to reduce this medical image size, allowing easier compliance with storage and network requirements (8).

PACS helps to achieve ubiquitous computing environment which should support and include either mobile or embedded devices owning different power, storage, communication, and display capacities, all served from one source and for various end usage (9, 10). PACS has maximum efficiency and minimum requirements when the source is a compressed medical image (lossless or lossy) with a compression technique that achieves small spatial distortion and supports image streaming (11, 12). Lossless compression reduces a file's size with no loss of quality. A file compressed using lossy compression may be one tenth the size of the original, while lossless compression is unlikely to produce a file smaller than half of the original size (64). On the other hand, lossy compression provides high degrees of compression and result in smaller compressed files, but there is a certain amount of visual loss when restored (65). Compression standard such as JPEG is used to create lossless compressed medical images.

2.2.1. Joint work with JPEG

JPEG (Joint Photographic Expert Group) is a standard adopted by both the International Standards Organization (ISO) and International Telegraph Union Telecommunications standards in 1983 for compression of digital images (22).

For the joint work with JPEG which is a standard of compression, the goals of this common work with DICOM and PACS are – to reduce digital image file sizes by compression in order to ensure rapid transmission of data (21), and – to address data storage as solution to that issue. The JPEG compression in daily practice offers an opportunity to further cost effective and efficient management of medical imaging data (22).

Some still image compression standards can be interfaced with PACS such as JPEG with a variety of proprietary compression techniques. JPEG compression has several advantages over other compression techniques (13, 14). The use of JPEG significantly reduces the size of the PACS medical image archive (15). It achieves superior compression performance with minimal spatial distortion within decompressed images, enables high quality image streaming, and it is an industry approved standard accepted by Digital Image and Communication in Medicine, called DICOM.

DICOM is a communication protocol usually used in PACS (16). The DICOM standard defines the DICOM message format, the protocol for message interchange and the file structure for biomedical images and image-related information (17, 18, 19, and 20). A DICOM message consists of two parts:

- The message header containing descriptive information about the medical image, patient, medical study etc.

- The image data containing pixels of the medical image in native DICOM format which is raw and uncompressed (17).

The integration of the DICOM standard has to be extended to support image streaming and a mechanism for communicating medical imaging information. This extension for DICOM standard implementations will enable quick, easy and transparent integration of the PACS in the health environment. It will achieve good results related to medical imaging storage and communication and will enable fast medical image browsing inside DICOM networks (15).

Through experience, it is seen that with the need to reduce storage requirements, transmission cost, and implementation of modern image processing techniques in hospitals, JPEG radiologic imaging compression is a must. It can also contribute in every step of the medical image processing chain, including image reconstruction, restoration, enhancement, feature extraction, object recognition, image understanding, optimization and surely compression (23).

2.3. Understanding benefits of the integration of DICOM based PACS intertwined with EHR and RIS

In order to enhance and support the quality delivery of radiology services in a hospital, a study indicated that RIS applications installed in a hospital concomitantly with PACS enabled online diagnostic reporting, patient scheduling, tracking of patient images and billing while PACS was allowing an efficient storage, processing, management and retrieval of patient data and images. As for HIS, the same study reported that it was responsible of important benefits including patient registration, quick clinical result reports, admission and discharge (26).

In CANADA, the technologies of DICOM/PACS and its related technologies (HER, RIS…) in health care settings improved the effectiveness and efficiency of diagnostic imaging service areas (Ultrasound, Mammography, Diagnostic x-ray, CT scan, virtual colonoscopy, Magnetic

Resonance Imaging etc..), workflow redesign and the introduction of PACS and DICOM into a Electronic Health Record framework has enabled referring physicians in their offices to securely access the diagnostic imaging reports images for their patients as soon as they are available. To shorten the radiology turnaround time, medical image exam requests are processed online through the Radiology Information System (RIS) (24).

Then, EHR is a beneficial solution interfaced with DICOM/PACS to facilitate paperless operation for a medical imaging department. It eliminates the shelves of patient image film result, x-ray billing loss, x-ray papers' request and so on.

2.3.1. DICOM/PACS utility and cost savings

Cost savings can be observed on the side of patients where these latter can find their image results in the referring doctor's consultation room. Their medical x-ray examinations' requests can quickly or easily reach x-ray imaging examination room. The waiting time of billing of medical x-ray examination can be reduced.

On a system-wide basis, not only the security and the privacy of data imaging are to be considered: PACS organizations reported that in Canada there was an annual national estimated benefit of $ 370 million when the online viewing of images and reports was available to specialists across the country. This was also due to the fact that film processing, storage and transportation costs were reduced and virtually replaced in a filmless environment (24).

In addition, a benefit of time saving is reported by study conducted by the University of California Davis Health System where "before the implementation of the system, physicians reported that they spent an average of 1 to 2 hours looking for hard copy films during the day." (25). After the implementation of the system, the total search time decreased to less than 1 hour for all patients. Before PACS implementation, when physicians wanted to take films from the radiology department, images were taken out of the radiology department because physicians would store them in multiple locations around the hospital in their offices, patients' rooms or conference rooms. But after implementation of the PACS system, with radiology images online, the physicians could always find the images they needed. Additionally, the same study reported that 14.1 minutes saved per x-ray study process represented 85.937 hours of physician time saved per year. The number of x-ray film jackets also decreased in after PACS implementation (25).

2.3.2. Increased productivity and quality of healthcare service delivery

The acquisition of DICOM based PACS and related technology can be beneficial in terms of productivity of radiology staff and the quality of care delivered to the patient. Medical imaging information of a patient can be entered and stored only once and becomes immediately available for other X-ray imaging processes. A PACS solution also eliminates the need for a redundant routine data entry, lengthy paper based registration procedures or appointment scheduling and reduces operational errors and duplication. It shortens the process chain and allows radiology technicians to perform more x-ray exams per day.

Some researchers reported that the improved productivity of radiology technologists associated with the use of PACS significantly reduced the X-ray processing time leading to higher productivity and better management of staff shortage, improving overall operational efficiency (28).

Considering the above benefits, we will conduct a research study focusing on the analysis of clinical, financial and technical cost-benefits of integrating DICOM and PACS at CHUK. The study results may play a role in adopting DICOM/PAC technology in CHUK.

CHAPTER 3. METHODOLOGY

This chapter presents the research methodology of the study which includes the following points: the study area, the study design, the study population, the study sample, the sampling strategy, the data collection methods and procedures, the data analysis, the problems and limitations of the study and finally the ethical considerations.

3.1. Study area

This study was carried out in CHUK, situated in the centre of the Kigali city on KN 4 AVE, Rwanda where the researcher is employed. CHUK is the biggest of the three Kigali based referral hospitals in Rwanda. It hosts 534 beds and has a wide offer of various specialized medical services (Gynecology and Obstetrics, Internal medicine, Clinic specialties, pediatrics, surgery and mental health). The health facility employs in clinical area a number of specialists from Rwanda and from Human Resource for Health (USA), general practitioners, allied staff and registered nurses. It serves as a medical reference and teaching hospital for medical students of University of Rwanda

3.2. Study design

The study was both quantitative and qualitative in nature because it respectively included measurements, statistical data and descriptions of phenomenon by observing what the study population did and said. The study design was retrospective; descriptive, analytic and focused on the financial costs and income of the radiology department. Afterward, trends of financial costs and income were generated.

In addition, we determined clinical and technical appreciation of PACS and DICOM standards by users.

The study covered a period from 29/1/2014 to 15/11/2014 during which sufficient data could be collected, analyzed and interpreted.

3.3. Study population

The study population mainly included patients who underwent medical imaging exams in the radiology department of CHUK. Those later were essentially patients from internal medicine, pediatrics, surgery, gynecology and obstetrics, clinical specialties and radiology departments of CHUK. This research needed also financial and administrative information from finance staff and human resource staff in order to find out financial and administrative reasons of integrating DICOM/PACS at CHUK.

3.4. Study sample

The study sample included 120 patients who had a medical imaging exam according to the sampling strategy explained below. The study involved 6 healthcare departments: radiology, surgery, internal medicine, gynecology and obstetrics, pediatrics, and clinical specialties.

3.5. Sampling strategy

In the sampling strategy, the population of 120 patients was randomly sampled as follows:
20 admitted patients scheduled for x-ray examinations were randomly selected in each of the following departments: radiology, surgery, internal medicine, pediatrics, clinical specialties, and gynecology and obstetrics. Random sampling was done by selecting every fourth patient presenting for x-ray examination in each department, providing a total of 120 patients.

Additionally, we randomly sampled 1 healthcare provider from each department of the five major departments at CHUK surgery, internal medicine, gynecology and obstetrics, pediatrics and clinical specialties. The members of this sample were expected to provide answers to clinical issues of radiology service delivery. The selected healthcare providers therefore had to be nurses or physicians.

Moreover, we sampled a total of three staff members from the radiology department, more precisely the head of the department, one radiology technologist, and one radiology technician. They served as source of information related to technical radiology imaging issues. For answering questions related to financial and administrative issues, we finally randomly selected one budget officer, one cashier, one pharmacist and one human resource agent in charge of remuneration.

3.6. Data collection methods and procedures used

For our research, we used focused group interviews using a questionnaire template and activity and financial reports for the last three years from which only relevant data was copied and processed.

Methods used for conducting this study included: requirement

1. Contacting individuals with skills in digital imaging radiology and imaging standard technology related to my study for sharing their expertise in order to meet my requirements.
2. Reviewing the results of recent related and similar studies

3.7. Data analysis

The data collection and analysis was performed and processed using the Microsoft Excel 2007 data analysis tool pack using tables and graphs. The writing of the text was harmonized and done with Microsoft Word 2007.

3.8. Problems and limitations of the study

i. Problems

1. The major problem for conducting this study was the shortage of funds.
2. We also found it difficult to get access to the price lists of the equipment required for the integration of DICOM based PACS.
3. Other logistical constraints we encountered were the resistance to letting the researcher access and manipulate radiology devices, the stock outs of radiology consumables and radiological modalities being down.

ii. Limitations

Due to the time and financial constraints, we limited the extensity of our research to only one relatively large referral hospital of Rwanda (CHUK). The replication of the study at other national referral hospital would enable better generalization of the findings revealed interesting.

3.9. Ethical Considerations

- Permission to carry out the study in CHUK was obtained from the CHUK clinical research department.
- The respondents were informed about the study objectives before being questioned and the data collected remained confidential and was used only for the stated research purposes.
- In order to guarantee confidentiality, the respondents were reassured that the questionnaire forms did not bare their names but were identified by a code.
- The respondents were requested to sign an informed consent form;
- The authors mentioned in this study were acknowledged within the references;
- The findings were presented in a generalized depersonalized manner.

CHAPTER4. PRESENTATION OF RESULTS

4.1. Technical reasons for integrating DICOM based PACS

4.1.1. Existing problems during daily radiology activity

Table 4.1 indicates the existing chronic problems complained by radiology staff during their daily activities. According to the daily activities plan, we identified the most often frequent clinical, financial and technical problems radiology staff encounter on a daily basis in the radiology department’s subunits.

Table 4.1: Existing problems encountered during daily radiology activity

Radiology staff level	Encountered problems in daily radiology activities
Radiology technologist	• All demographic data of patients consulting radiology department are recorded in the registers. • The scheduling of patient is paper based for all radiology examinations (lack of information system scheduling workflow) • Difficulties to control daily volume of radiology exams done • Many duplication errors • A lot of complaints of loss of radiology imaging results • Insufficient space for receiving patients • Radiology technicians working as receptionists • Non-computerized reception (lack of EHR/ Open Clinic) • Problematic image transfer workflow due to simultaneous in- and out-patient examination requests
Cashier	• Uncontrolled billing system: the number of medical imaging exams listed in the register to be paid does not always match with the examined number of medical imaging exams which have already paid in the Open Clinic, the medical imaging x-ray exams wrongly printed are not paid or found in the

	billing system when they are reproduced again. • Absence of a billing system linked automatically to performed medical image examinations ordered by a referring physician. • Some of the medical x-ray image procedures are not recorded into the billing system by the cashier: Some relatives of hospital staff and some hospital staff do not pay the medical imaging examinations they underwent in the radiology department.
Radiology technician in charge	• High volume of work load. • Patient's x-ray examination room overcrowded • Staff shortage • High level of stress and fatigue • Low patient, physician and nurses' satisfaction of radiology service delivery. • Long delay before getting access to medical x-ray image results leading also delaying clinical support to patients in sometimes acute situations • Every x-ray exam ordered is said urgent • Unrestricted access to x-ray image results • High rate of complaints of loss of medical x-ray image results • Long film processing time • The increased use of imaging techniques • The increased number of different medical diagnostic x-ray modalities • Daily high number of unreported medical x-ray images. • Lack of a health information system linking the radiology department to the other clinical departments (no RIS available).

	• Time consuming procedures of film processing, reporting medical x-rays results, recording of patient demographics... • Unsatisfied radiology technologists by their quality of medical imaging service delivery. • Lack of x-ray medical images storage space: physical and electronic.
Radiologist head of Department	• Poor workflow management due to the lack of information systems such as Open Clinic in the radiology department to help referring physicians with medical imaging order-entry. • Poor management of x-ray image hard copies storage space. • Lack of collaboration with other clinical departments • Low income generated • Shortage of radiologists • High workload • Low competition spirit of radiology staff comparing to the competition of radiology staff of private hospital • Insufficient staff productivity • Low numbers of interpreted medical x-ray image results. • Poor security and privacy for patient's medical x-ray results • The radiology system is still film based • Difficulties to recover a patient medical x-ray image once it's lost. • There is no organized information system in the department. • The use of x-ray modalities from different vendors which can't interoperate. • Long waiting time for patients arriving to the radiology department.

4.1.2. Available digital x-ray imaging modalities' vendors and information system interfaces

The difficult implementation of interoperability of various digital x-ray imaging modalities interfaced with various information systems may be a technical burden for radiology department. Table 4.2 shows that most of available x-ray imaging modalities are from different vendors: 4/8 x-ray imaging modalities are from Siemens, 3/8 are from General Electric and 1/8 from Philips. None of them are interfaced with any information systems including DICOM, PACS, JPEG, HIS, RIS, HL7except for the computed tomography which is interfaced with a mini PACS.

Table 4.2: Available digital x-ray imaging modalities' vendors and interfaced information systems

X-ray imaging modalities	Total number of available digital x-ray imaging modality in place	Vendor of the x-ray imaging modalities	Information technology systems interfaced with x-ray imaging modalities
Fluoroscopy	1	Siemens	No DICOM, PACS, RIS, HIS, HL7,JEPG
Mammography	1	Siemens	No DICOM, PACS, RIS, HIS, HL7,JEPG
Computed Tomography	1	Siemens	No DICOM, RIS, HIS, HL7,JEPG,**Yes Mini PACS**
General Radiography	1	Philips	No DICOM, PACS, RIS, HIS, HL7,JEPG
General Radiography	1	Siemens	No DICOM, PACS, RIS, HIS, HL7,JEPG
3 Mobile general radiography	3	General Electronics	No DICOM, PACS, RIS, HIS, HL7,JEPG

4.1.3. Time duration between x-ray exam order and patient arrival in x-ray examination room

Clearly, table 4.3 shows that the time elapsed between a patient's x-ray examination order and his arrival at the x-ray examination room is considerably longer, as recorded in different clinical departments.

For CT-scans in surgery, 56 hours 20 minutes was the time between its order and patient arrival in x-ray examination room, followed by clinical specialties with 31 hours 12 minutes and internal medicine with duration varying from 52 minutes up to 16 hours 55 minutes.

At the department level, the data indicated that 26 hours 49 minutes (more than 1day) was the top department mean time elapsed between a patient's x-ray examination order from Gyn-Obs and his arrival at the x-ray examination room, followed by surgery department where 21 hours 19 minutes was the time passed between patient's x-ray exam order and his arrival in x-ray examination room.

And at the hospital level, 24 hours 06 minutes was considered as the high hospital mean duration between CT scan exam order and patient arrival in x-ray examination room. From this point of view, the patient overall length of stay in hospital is varying in accordance with the length of time between patient x-ray exam order and patient arrival in x-ray examination room.

Table 4.3: **Time duration between x-ray exam order and patient arrival in exam room**

X-ray examination orders	Time duration between patient's medical x-ray examination order and patient arrival in x-ray examination room/Department					
	Surgery (N=20)	**Internal Medicine (N=20)**	**Gyn-Obs. (N=20)**	**Pediatrics (N=20)**	**Clinical specialties (N=20)**	**Hospital mean**
General radiography medical x-ray examination	15 h 25 min (N=10)	13 h 50 min (N=6)	6 h 06 min (N=5)	2 h 10 min (N=7)	5 h 05 min (N=10)	8 h 31 min
CT Scan medical x-ray examination	56 h 20 min (N=2)	16 h 55 min (N=3)	8 h 32 min (N=2)	7 h 31 min (N=3)	31 h 12 min (N=4)	24 h 06 min
Fluoroscopy medical x-ray examination	3 h 36 min (N=1)	1 h 40 min (N=2)	1 h 29 min (N=1)	1 h 09 min (N=3)	26 h 36 min (N=2)	6 h 54 min
Mammography medical x-ray examination	4 h 55 min (N=3)	52 min (N=1)	2 h 03 min (N=7)	1 h 12 min (N=2)	18 h 19 min (N=1)	5 h 28 min
Special radiography medical x-ray examination	26 h 21 min (N=4)	12 h 25 min (N=8)	8 h 39 min (N=5)	9 h 09 min (N=5)	5 h 10min (N=3)	12 h 20 min
Department mean	21 h19 min	7 h 08 min	26 h 49 min	4 h 00 min	17 h 16 min	
***Overall length of stay in hospital (days)**	11 days	10 days	3 days	11 days	0 days	

*** Source of** *Overall patient stay time in hospital (day); data from KUTH's statistics department.*

4.1.4 Time duration spent in the medical x-ray examination room

The figure 4.2 indicates the time spent in the x-ray examination room. A total number of 20 patients were monitored in the radiology department. The results showed that 75 minutes was the major time spent in the medical x-ray room for CT scan examination and followed by 50 minutes as the time spent in fluoroscopy examination room for fluoroscopy examinations compared to 22 minutes found as the lowest time spent in the medical x-ray examination room relating to mammography examination.

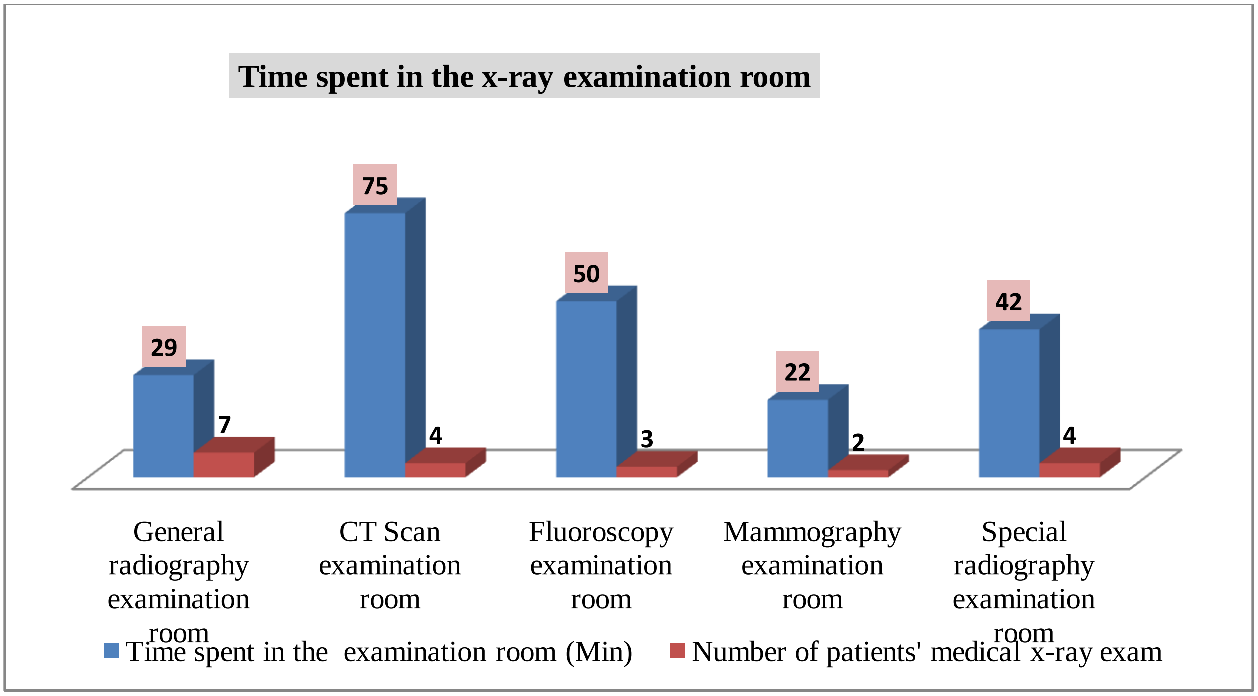

Figure 4.2: Time spent in the x-ray examination room

4.1.5. Time duration to complete an x-ray exam

The figure 4.3 indicates the time it takes for an x-ray exam to be completed. 145 minutes, 94 minutes and 83 minutes were the high measured mean time duration found for respectively completing a CT scan, a special radiography x-ray examination and a fluoroscopy x-ray examination.

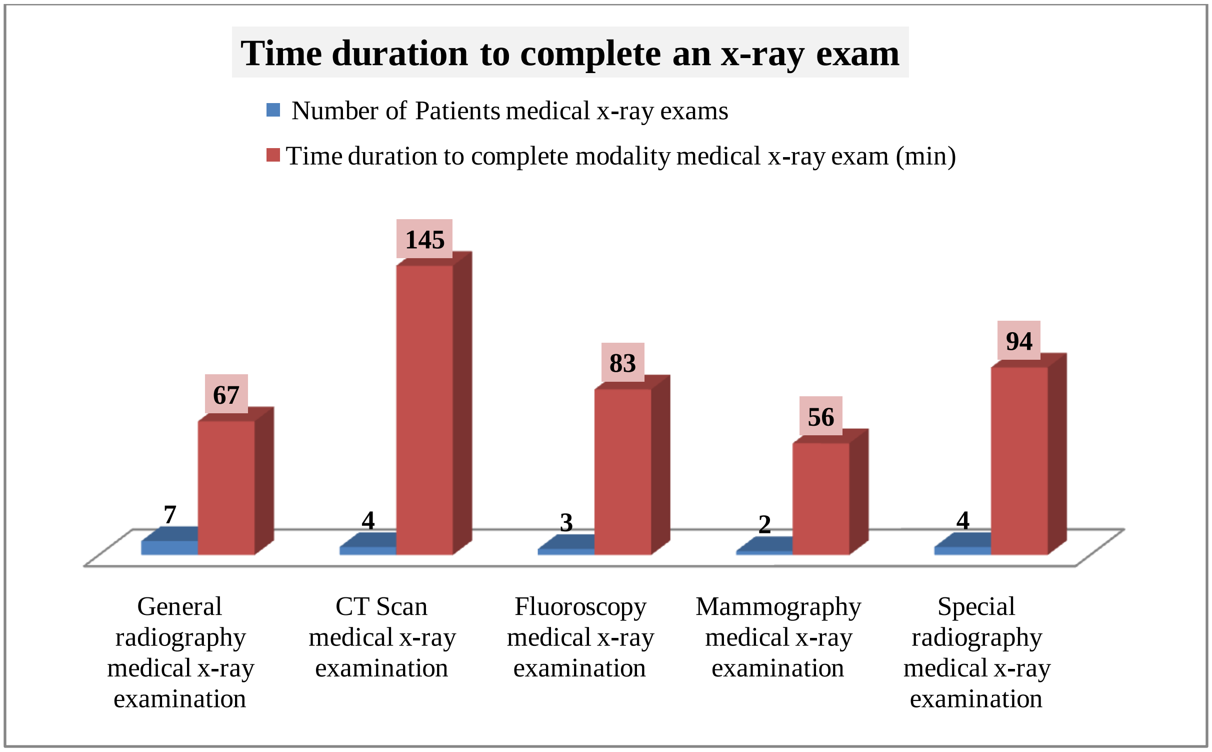

Figure 4.3: Time duration to complete an x-ray exam

4.1.6. Time duration made to develop a medical x-ray image

Figure 4.3 shows that 70 minutes was the highest time elapsed to develop a CT scan image from the lowest time duration observed on the figure which was 25 minutes respectively related to the time spent to develop a general radiography image and a fluoroscopy image.

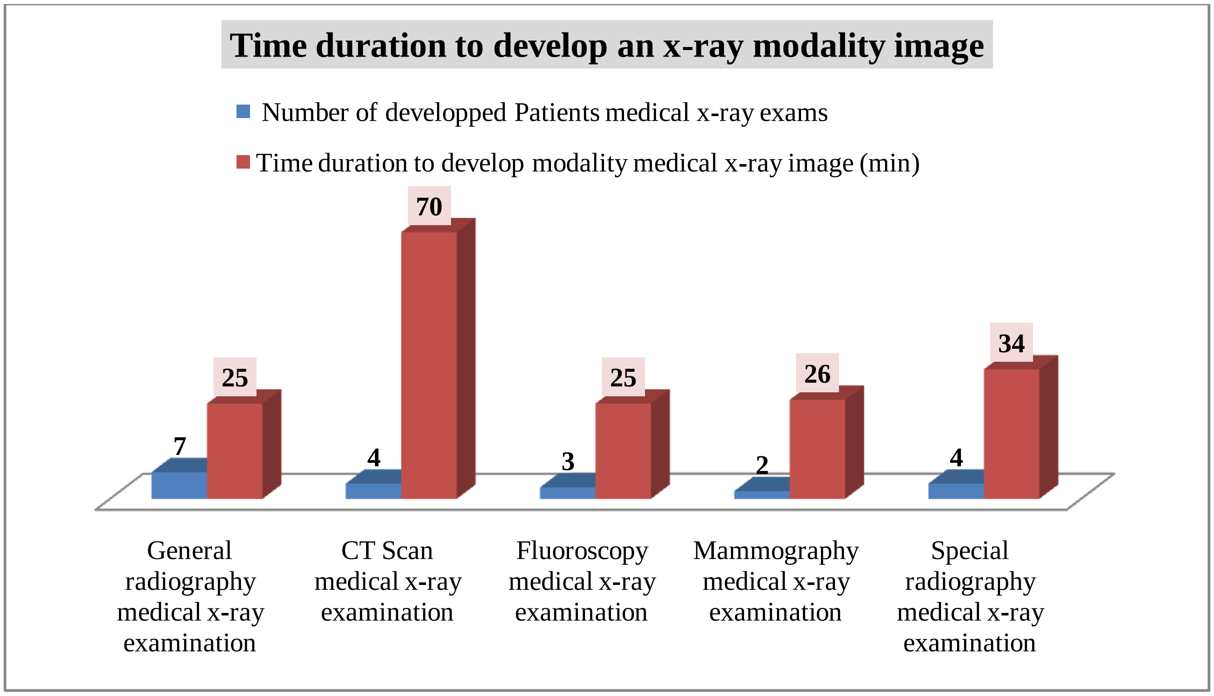

Figure 4.4: Time duration to develop an x-ray modality image

4.1.7. Patient demographic data recording time and radiologist reporting turnaround time

Table 4.4 presents patient demographic data recording turnaround time and the radiologist reporting turnaround time of different types of medical x-ray exams ordered by physicians. The results showed that 1 hour 32 minutes was the top turnaround time to record the demographic data of a patient consulting for general x-ray exam, followed by 1 hour 09 minutes which was a time elapsed for recording demographic data of a patient consulting for a special x-ray exam while 58 minutes were considered as the general mean time took to record the demographic data of a patient consulting for an ordered x-ray exam.

And from 5 hours 15 minutes which was the hospital mean turnaround time for an ordered x-ray exam reporting, 19 hours 24 minutes was the highest turnaround time for radiologist to report a CT scan exam.

Table 4.4: Patient demographic data recording and radiologist reporting turnaround time

Ordered medical x-ray exams	Patient demographic data recording turnaround time	Radiologist x-ray reporting turnaround time
Computed tomography x-ray exams(CT Scan)(N=4)	44 min	19 h 24 min
General x-ray exams(N=7)	1 h 32 min	2 h 43 min
Fluoroscopy x-ray exams(N=3)	49 min	1 h 09 min
Mammography x-ray exams(N=2)	38 min	1 h 05 min
special x-ray exams(N=4)	1 h 09 min	1 h 58 min
Mean time/ ordered x-ray exam	58 min	5 h 15 min

4.1.8. Time for distributing, processing x-ray film requests and time patients spend in radiology

Table 4.5 shows various time duration of some steps each patient goes through to access radiological services. The main time of steps mentioned in our study are broadly time used for distributing; viewing films and handling other film requests, time between two x-ray film processing and approximate time patients spend in the radiology department.

Among the time spent for distributing, viewing and handling various requested x-ray examinations mentioned in the table, the high length of time observed was 5 hours 25 minutes used for distributing, viewing CT scan film result or handling other related CT scan film requests and 2 hours 18 minutes spent for distributing, viewing or handling a general x-ray film result while 1 hour 58 minutes were the hospital mean time necessary for distributing, viewing or handling an x-ray film result.

The same table also indicates that 1hour28 minutes was the top time between 2 CT scan film results' processing procedures, followed by 52 minutes which were also the time between 2 special x-ray film results printings by referring to 39 minutes considered as the lowest gap between 2 general x-ray film results processing.

Regarding the approximate time patients spent in radiology department, patient consulting for CT scan services were apparently spending 29 hours 26 minutes and this latter was the highest time a patient spent in radiology department.

Table 4.5: Time for distributing, processing x-ray film requests and time patients spend in radiology

X-ray film results	Time needed for distributing, viewing and handling other film requests (N=120)	Time between 2 x-ray film processing procedures (N=20)	Approximate time spent by patient in radiology department (N=120)
CT scan x-ray film results	5 h 25 min (N=18)	1 h 28 min (N=4)	29 h 26min (N=18)
General x-ray film results	2 h 18 min (N=45)	39 min (N=7)	8 h 06min (N=45)
Fluoroscopy x-ray film results	45 min (N=12)	45 min (N=3)	4 h 43min (N=12)
Mammography x-ray film results	29 min (N=16)	48 min (N=2)	3 h 48 min (N=16)
Special x-ray film results	56 min (N=29)	52 min (N=4)	6 h 11 min (N=29)
Hospital mean time/ an x-ray film results	1 h 58 min	54 min	10 h 26 min

4.1.9. A view on radiology department staff shortage/cost

Table 4.6 reveals the avoidable radiology department staff shortage and its related budget cost. The actual hospital radiology staffing on day and night duty was summing up to a total of 16 budgeted for FRW 77,426,400 in the budget year of 2013-2014. The same table shows that this radiology department was understaffed with a staff gap of 5 radiology staff. Whereas, the planned budget for the needed radiology staff (5) was FRW 25,458,000. Then, we found that the total budget for the radiology staffing including the budget of current staff plus the budget of the needed staffing was FRW 102,884,400.

Table 4.6: Staff shortage in the radiology department/cost

Radiology department unit (Staff type)	Current budgeted staffing number 2013-2014		Off	Total budget for current radiology staffing	Needed staffing (or gap) 2013-2014	
	Staff number on day duty	Staff number on night duty			Number of needed staff	Yearly budget cost of the needed staff (FRW)
Reception desk/ Various activities (librarian and radiology technician)	2	0	2	4,659,600	1	3,607,200
2 general x-ray examination rooms (radiology technicians)	2	1		10,821,600	1	3,607,200
CT-scan examination room (radiology technician)	1	1		14,428,800	2	7,214,400
Fluoroscopy/Mammography x-ray examination room (radiology technician)	2	0		7,214,400	0	0
Support staff (Nurses)	2	0		7,214,400	0	0
Modality medical x-ray reporting room (radiologists)	3	0		33,087,600	1	11,029,200
Total	12	2	2	**77,426,400**	**5**	**25,458,000**
				102,884,400		

***Source:** *CHUK new organization structure approved by MIFOTRA and MOH 03.2013*.

4.1.10. Compliance assessment related to the use of modality medical x-ray image

This compliance assessment was consisting in the evaluation of the use of modality medical x-ray image storage, retrieval, archiving, security and backup storage. Among the criteria considered were the evident use of electronic x-ray image storage time, presence of archiving system, presence of security system for patients' medical x-ray images, availability of x-ray image retrieval system and availability of x-ray image back up storage.

The findings show that only the storage modalities and the electronic x-ray image storage time lasting for up to 3 days were available only for CT scan x-ray images. For the remaining x-ray imaging modalities, the results indicate a lack of compliance on the criteria mentioned above.

Table 4.7: Compliance assessment related to the use of modality medical x-ray image

Modality medical x-ray images	**Electronic medical x-ray image storage time**	**Presence of medical x-ray image archiving system**	**Presence of security system for patients' medical x-ray images**	**Available medical x-ray image storage modalities (devices)**	**Available patients' medical x-ray images retrieving system**	**Medical x-ray image backup storage**
CT scan x-ray images	C (3 days)	N/C	N/C	C	N/C	N/C
General x-ray images	N/C	N/C	N/C	N/C	N/C	N/C
Fluoroscopy x-ray images	N/C	N/C	N/C	N/C	N/C	N/C
Mammography x-ray images	N/C	N/C	N/C	N/C	N/C	N/C
Special radiography x-ray images	N/C	N/C	N/C	N/C	N/C	N/C

*N/C: Non compliant. *C: Compliant

4.1.11. The reporting format of x-ray image results

According to the results in table 4.8, the reporting format for x-ray image results was predominantly paper based amid other reporting format for x-ray image results: 99% of reported CT scan image results were the top-ranked paper based reporting format, respectively followed by 90 %, 85% and 80% of reported mammography, fluoroscopy and special x-ray image results which were also paper based while 35% of reported CT scan x-ray image results were in CD based.

Table 4.8: The reporting format of Patient's medical x-ray image results

Medical x-ray image reporting format	Modality medical x-ray image results (N=20)				
	General radiography medical x-ray images (N=7)	CT Scan medical x-ray images(N=4)	Mammography medical x-ray images (N=2)	Fluoroscopy medical x-ray images (N=3)	Special medical x-ray images (N=4)
Paper based	65%	99%	90%	85%	80%
Online	0%	0 %	0%	0%	0%
Vocal based	0%	0%	0%	0%	0%
CD based	35%	1%	10%	15%	20%

4.2. Clinical reasons of integrating DICOM/PACS

4.2.1. Clinical staff turnaround time from clinical ward to the radiology department

Table 4.9 indicates the high average daily time spent by clinical staff moving from the clinical ward to the radiology department to look for x-ray results of hospitalized patients.

The findings show that for various requested x-ray images results from different departments, the IM has the top daily x-ray image lookup time: 2 hours15 minutes for fluoroscopy x-ray image results, followed by 2 hours 01 minutes for special x-ray image results and 1 hour 55 minutes for CT scan images results which were found above others. At the hospital level, 1 hour 30 minutes was the high average turnaround time of clinical staff moving from their clinical wards to the radiology department to look for CT scan x-ray image results, followed by 1 hour 25 minutes for looking up special x-ray image results.

Table 4.9: Clinical staff turnaround time from clinical ward to the radiology department

Modality medical x-ray image results	Clinical staff turnaround time from clinical ward to the radiology department					
	IM (N=20)	Surgery (N=20)	Pediatrics (N=20)	G-O (N=20)	Clinical Specialties (N=20)	Mean time /x-ray image results
CT scan x-ray images results	1 h 55 min	1 h10 min	1 h 02 min	1 h 40 min	1 h 45 min	1 h 30 min
General x-ray image results	1 h 10 min	1 h 20 min	45 min	50 min	40 min	57 min
Mammography x-ray image results	1 h 20 min	1 h 04 min	39 min	57 min	1 h 07 min	1 h 01 min
Fluoroscopy x-ray image results	2 h 15 min	49 min	49 min	1 h 32 min	57 min	1 h 16 min
Special x-ray image results	2 h 01 min	1 h 37 min	54 min	1 h 21 min	1 h 12 min	1 h 25 min
Mean time / department	1 h 44 min	1 h 12 min	49 min	1 h 16 min	1 h 08 min	

4.2.2. X-ray results reported or interpreted by radiologists

Table 4.10 shows the number of x-ray results reported or interpreted by radiologists versus the unreported ones that were needed during medical ward rounds in 4 selected clinical departments.

Among the reported x-ray image results requested in different departments during medical ward rounds, all the requested x-ray image results were not all reported by radiologists except for pediatrics department in which a total of 100% of x-ray image results requested during medical ward round were reported.

The same results show that during medical ward round in surgery 65% of requested x-ray image results were not reported and in clinical specialties 60% of requested x-ray image results were not reported. Then, Surgery and clinical specialties were the top ranked departments with high number of unreported x-ray image results during medical ward round.

Table 4.10: X-ray image results reported or interpreted by radiologists

Hospital departments	**Modality medical x-ray image results**	**Number of reported x-ray image results requested during medical ward round and their corresponding %**	**Interpreted or reported x-ray image results and their corresponding %**	**Uninterpreted or unreported x-ray results and their corresponding %**
IM	General radiography image results	6 (30%)	2 (10%)	4 (20%)
	CT Scan x-ray image results	3 (15%)	2 (10%)	1 (5%)
	Fluoroscopy x-ray image results	2 (10%)	2 (10%)	0 (0%)
	Mammography x-ray image results	1 (5%)	1 (5%)	0 (0%)
	Special radiography image results	8 (40%)	6 (30%)	2 (10%)
	Totals	**20 (100%)**	**13 (65%)**	**7 (35%)**
Surgery	General radiography x-ray medical x-ray image	10 (50%)	1 (5%)	9 (45%)

	results			
	CT Scan x-ray image results	2 (10%)	1 (5%)	1 (5%)
	Fluoroscopy x-ray image results	1 (5%)	0 (0%)	0 (0%)
	Mammography x-ray image results	3 (15%)	2 (10%)	1 (5%)
	Special radiography image results	4 (20%)	3 (15%)	2 (10%)
	Total	**20 (50%)**	**7 (35%)**	**13 (65%)**
Pediatrics	General radiography image results	7 (35%)	7 (35%)	0 (0%)
	CT Scan x-ray image results	3 (15%)	3 (15%)	0 (0%)
	Fluoroscopy x-ray image results	3 (15%)	3 (15%)	0 (0%)
	Mammography x-ray image results	2 (10%)	2 (10%)	0 (0%)
	Special radiography image results	5 (25%)	5 (25%)	0 (0%)
	Total	**20 (100%)**	**20 (100%)**	**0 (0%)**
Gyn-Obs	General radiography image results	5 (25%)	2 (10%)	3 (15%)
	CT scan x-ray image results	2 (10%)	1 (5%)	1 (5%)
	Fluoroscopy x-ray image results	1 (5%)	1 (5%)	0 (0%)
	Mammography x-ray image results	7 (35%)	3 (15%)	4 (20%)
	Special radiography image results	5 (25%)	4 (20%)	1 (5%)

	Total	**20 (100%)**	**1 (55%)**	**9 (45%)**
Clinical specialties	General radiography x-ray image results	10 (50%)	3 (15%)	7 (35%)
	CT Scan medical image x-ray results	4 (20%)	1 (5%)	3 (15%)
	Fluoroscopy x-ray image results	2 (10%)	2 (10%)	0 (0%)
	Mammography x-ray image results	1 (5%)	1 (5%)	0 (0%)
	Special radiography image results	3 (15%)	1 (5%)	2 (10%)
	Total	**20 (100)**	**8 (40%)**	**12 (60%)**

4.2.4. The cost and number of lost x-ray film results before being delivered to their patient

Table 4.11 below illustrates the number and cost of lost x-ray film during the medical ward round before being delivered to patients. The reproduction of the lost x-ray image results was also considered as loss in terms of cost and number of x-ray films because they were reproduced free of charged.

Clinical specialties was the leading department to lose high number of x-ray films where 12 x-ray films were lost (6lost before the ward round started and 6 reproduced in order to replace the lost ones). The daily total cost of loss was FRW 473,200 for both the lost and reproduced x-ray films and within a year the total cost of loss could be FRW 172,718,000., and followed by the surgery where 8 x-ray films were lost (4 were lost before being delivered to the patients and 4 others were reproduced. Their daily and yearly total costs of loss were respectively around FRW 291,975 and FRW 106,569,415.

In total and for various x-ray film results to be delivered to the patients before the medical ward round, 22 x-ray were daily lost and the extrapolation of that loss to a year was 8030 of x-ray films with a yearly cost of loss of 294,069,915 FRW.

Table 4.11: Cost and number of lost x-ray film results before being delivered to their patient

Hospital departments	Modality x-ray imaging results	Number of requested x-ray image results during medical ward round	Lost x-ray film results/ day (medical ward round)	Reproduced number of lost x-ray film results (medical ward round)	Cost of lost x-ray film results/day (FRW) (medical ward round)	Estimated total yearly cost of lost x-ray film results (FRW)
IM	General radiography image results	6	1	1	40,500	14,782,500
	CT Scan x-ray image results	3	0	0	0	0
	Fluoroscopy x-ray image results	2	0	0	0	0
	Mammography l x-ray image results	1	0	0	0	0
	Special radiography x-ray images	8	0	0	0	0
	Total	**20**	**1**	**1**	**40,500**	**14,782,500**
Surgery	General radiography image results	10	3	3	51,975	18,969,415
	CT Scan x-ray image results	2	1	1	240,000	87,600,000
	Fluoroscopy x-ray image results	1	0	0	0	0
	Mammography x-ray image results	3	0	0	0	0
	Special radiography x-ray image results	4	0	0	0	0

	Total	**20**	**4**	**4**	**291, 975**	**106,569,415**
Pediatrics	**General radiography image results**	7	0	0	0	0
	CT Scan x-ray image results	3	0	0	0	0
	Fluoroscopy x-ray image results	3	0	0	0	0
	Mammography x-ray image results	2	0	0	0	0
	Special radiography x-ray image results	5	0	0	0	0
	Total	**20**	**0**	**0**	**0**	**0**
G-O	**General radiography x-ray image results**	5	0	0	0	0
	CT Scan x-ray image results	2	0	0	0	0
	Fluoroscopy x-ray image results	1	0	0	0	0
	Mammography x-ray image results	7	0	0	0	0
	Special radiography x-ray image results	5	0	0	0	0
	Total	**20**	**0**	**0**	**0**	**0**
Clinical specialties	**General radiography image results**	10	5	5	173,200	63,218,000
	CT Scan x-ray image results	4	1	1	300,000	109,500,000
	Fluoroscopy x-ray image results	2	0	0	0	0
	Mammography x-ray image results	1	0	0	0	0

	Special radiography x-ray image results	3	0	0	0	0
	Total	**20**	**6**	**6**	**473,200**	**172,718,000**
Total			**11**	**11**	**805,675**	**294,069,915**

4.3 Financial reasons for DICOM/PACS integration

This section presents financial cost issues related to x-ray processing management, other various types of x-ray film losses and different radiology activities expenditures which were occurred in radiology department.

4.3.1. Yearly estimated total cost expenditure of x-ray image processing

X-ray consumables, x-ray films and personnel outside radiology (like porter and librarian) are also the elements that are mainly involved in the increasing of the cost expenditures of x-ray image processing activities. These latter may also increase the yearly total cost of x-ray image processing expenditures in the radiology department.

Table 4.12 shows that FRW 106,733,844 were a yearly average total expenditure of main elements involved in x-ray image processing, including FRW 7,693,825 as a yearly average total expenditure for x-ray consumables, FRW 97,690,019 a yearly average total expenditure for x-ray films and FRW 1,350,000 as a yearly average total expenditure for personnel outside radiology.

For 2012, the fall of estimated total expenditure cost of x-ray image processing (FRW 65,214,891) was justified by the stock run out of x-ray films before the planned time of utilization and the delay of the procurement office to revise another new budget for x-ray film purchase.

Table 4.12: Yearly estimated total expenditure cost of x-ray image processing

Processing Year	Cost of x-ray consumables (FRW)	X-ray film cost (FRW)	Cost of personnel outside radiology(porter) (FRW)	Estimated total expenditure cost of x-ray image processing/year
2010	10,156,891	98,506,502	1,440,000	**110,103,393**
2011	10,743,521	97,356,180	1,440,000	**109,539,701**
2012	9,776,821	54,178,070	1,260,000	**65,214,891**
2013	98,069	140,719,325	1,260,000	**142,077,394**
Total	**30,775,302**	**390,760,077**	**5,400,000**	**426,935,379**
Yearly average cost	**7,693,825**	**97,690,019**	**1,350,000**	**106,733,844**

***Source:** CHUK *radiology department: Monitoring and evaluation report of 5year strategic plan (CHUK, 2013)*

4.3.2. Cost of total number of erroneous prints or unusable x-ray film results

The financial burden for the radiology department is the x-ray film results printed with errors and which are thrown away as disposal material. These latter considered as a loss in terms of quantity number and cost may be avoidable.

According to table 4.13, even if the results show that there was a progressive decrease of yearly number of x-ray films results printed with errors from 204 (in 2010) to 89 (in 2013), the cost also dropped down from FRW 3,846,150 (in 2010) to FRW 1,458,900 (in 2013). Then, the average number of erroneous x-ray films results printed was 145 for a cost of loss of FRW 2,476,825.

Table 4.13: Cost of total number of erroneous prints or unusable of x-ray film results

Time	Annual number of erroneous prints or unusable x-ray films				
	2010	**2011**	**2012**	**2013**	**Average**
Total	**204**	**153**	**134**	**89**	**145**
Cost (FRW)/year	**3,846,150**	**2,408,250**	**2,194,000**	**1,458,900**	**2,476,825**

Source:** ***CHUK *Radiology department: yearly situation report of radiology quality improvement: Monitoring waiting times and activity (2010, 2011, 2012 and 2013)*

4.3.3. The cost of loss for duplicated x-ray image results

Based on the loss usually observed during x-ray imaging malpractice and workflow mismanagement, some requested x-ray images were duplicated. Therefore, this duplication of x-ray image results was not requested and was considered as a loss in terms of cost and number of x-ray film.

Among the results described in the table 4.14, 5/45 general x-ray image requested and 2/29 special x-ray image requested were considered as the top number of x-ray image duplicated per day amid other types of x-ray images requested. Therefore, the corresponding daily cost was respectively around FRW 86,625 and FRW 85,050 and within a year the data show that the number of duplication of general x-ray radiography image results and special radiography x-ray image results respectively reached 1,825 and 730 with respective yearly costs of FRW 31,618,125 and FRW 31,043,250.

A total of 2,555 x-ray image results could be duplicated within a year with a yearly cost of loss of FRW 62,661,375.

Table 4.14: The cost of loss for duplicated x-ray image results

Duplicated x-ray image results	Daily number	Daily cost of loss (FRW)	Approximate yearly number	Approximate yearly cost of loss (FRW)
General radiography x-ray image (N=45)	5	86,625	1,825	**31,618,125**
CT scan x-ray images(N=18)	0	0	0	0
Fluoroscopy x-ray image (N=12)	0	0	0	0
Mammography x-ray image (N=16)	0	0	0	0
Special radiography x-ray image (N=29)	2	85,050	730	**31,043,250**
Total	7	171,675	2,555	**62,661,375**

4.3.4. The daily cost and number of lost x-ray image results within the radiology department

The radiology technical carelessness leads to a loss in terms of cost and number of x-ray image results in the radiology. Therefore, the cost of x-ray image results lost within the radiology department is financially considered as burden.

As indicated in table 4.15, 9 general x-ray radiography image results were the only x-ray image results lost per day within the radiology department with a daily cost of FRW 155,925. Therefore, in a year the loss of general x-ray radiography image results was 3,285 with a cost of FRW 56,912,625.

Table 4.15: **The daily cost and number of lost x-ray image results within the radiology department**

Lost modality medical x-ray image results	**Daily number**	**Daily cost** (FRW)	**Approximate yearly number**	**Approximate yearly cost** (FRW)
General radiography x-ray image results (N=45)	9	155,925	3,285	56,912,625
CT scan medical x-ray results(N=18)	0	0	0	0
Fluoroscopy x-ray image results (N=12)	0	0	0	0
Mammography x-ray image results (N=16)	0	0	0	0
Special radiography x-ray image results (N=29)	0	0	0	0
Total	9	155,925	3,285	**56,912,625**

4.3.5. The cost and number of unbilled performed x-ray imaging procedures

A certain number of performed x-ray imaging procedures were not billed or not found in the billing system. Therefore, the cost of the unbilled performed x-ray image procedures were financially considered as a loss.

In that view, table 4.16 indicates the cost and the number of unbilled x-ray imaging procedures performed per year. The most remarkable were 132 general x-ray radiography imaging procedures which were not found in the billing system with a corresponding cost of FRW 2,286,900. Followed by 84 unbilled special radiography imaging procedures with a cost of FRW 3,444,525. Therefore, 240 was a yearly total number of unbilled x-ray imaging procedures performed in the radiology department for a corresponding yearly total cost of FRW 6,671,700.

Table 4.16: **The cost and number of unbilled performed x-ray imaging procedures**

Unbilled performed x-ray imaging procedure/time (2013)	**Number of unbilled modality medical x-ray imaging procedures / clinical department**					**Total**
	General radiography (N=45)	**CT Scan (N=18)**	**Mammography (N=16)**	**Fluoroscopy (N=12)**	**Special radiography (N=29)**	
Unbilled performed x-ray imaging procedures /month	11	0	1	1	7	20
Unbilled performed x-ray imaging procedures/year	**132**	0	**12**	**12**	**84**	**240**
Cost of unbilled performed x-ray imaging procedures/Year (FRW**)**	**2,286,900**	**0**	**472,500**	**467,775**	**3,444,525**	**6,671,700**

***Source:** *http://openclinic.chukigali.org/openclinic/*

4.3.6. The cost of disposal of radiology waste materials

The disposal of radiology waste materials is considered by the hospital as a growing financial problem to be handled. The table 4.17 is clearly shows that, between 2010 and 2013, the quantity of disposal of radiology waste materials increased from 1,537 to 2,296 kg as well as its corresponding cost which increased from FRW 1,037,475 to FRW 1,549,800. And an average of 1.612 kg of radiology waste materials was supposed to be destroyed per year for a yearly cost of FRW 1,360,631.

Table 4.17: **Cost of disposal of radiology waste materials.**

Year	Radiology waste materials		
	Components	**Quantity (Kg)**	**Cost** (FRW)
2010	Chemicals, Film packet wrap, Films, Papers, plastic, light tight bag	1,537	1,037,475
2011	Chemicals, Film packet wrap, Films, Papers, plastic, light tight bag	2,111	1,424,925
2012	Chemicals, Film packet wrap, Films, Papers, plastic, light tight bag	2,119	1,430,325
2013	Chemicals, Film packet wrap, Films, Papers, plastic, light tight bag	2,296	1,549,800
Total		8,063	5,442,525
Yearly average		1,612	1,360,631

***Source:** *CHUK office of budget- Housekeeping services: clinical waste disposal contract reports (2010), (2011), (2012), (2013).*

4.3.7. The cost of paper based request forms for x-ray exams

The paper based request forms for x-ray exam are presented in radiology department by every patient consulting for any requested radiology service. As the quantity of these latter is regularly increasing, their cost budget is consequently increases.

Table 4.18 shows that the number of paper based x-ray exams request forms used in the last four budget years increased from 300 to 5,000 blocks with a corresponding cost varying from FRW 114,900 to FRW 2 ,858,900. 1,520 blocks could be considered as a yearly average quantity of paper based request forms of x-ray exam with a corresponding cost of FRW 808,120.

Table 4.18: Cost of paper based request forms for x-ray exams

Budget year	Quantity and cost of paper based request forms for x-ray exam	
	Quantity (block)	**Cost (**FRW**)**
B-Y 2010-2011	300	114,900
B-Y 2011-2012	500	256,800
B-Y 2012-2013	1,800	810,000
B-Y 2013-2014	5,000	2,858,900
Total cost	**7,600**	**4,040,600**
Yearly average cost	**1,520**	**808,120**

***Source:** *CHUK office of budget- fiscal year budget submission volumes (F-Y 2010-2011, F-Y2011 2012, F-Y 2012-2013, F-Y 2013-2014).*

4.4. Total sum of cost expenditures that could be avoided

The results below indicate that FRW 531,695,035 were the total sum of expenditures made within a year in radiology department.

Estimated total cost of lost x-ray film results before medical ward round/year (FRW)	**294,069,915**
Cost of medical x-ray image consumables (FRW)	**7,693,825**
X-ray Film cost (FRW)	**97,690,019**
Cost of personnel outside radiology(x-ray image porter) (FRW)	**1,350,000**
Cost of disposal used radiology materials (FRW)	**1,360,631**
Average yearly cost of erroneous prints of x-ray film results (FRW)	**2,476,825**

The cost of duplicated x-ray images /year (FRW)	**62,661,375**
Cost of lost x-ray film results within the radiology department / year (FRW)	**56,912,625**
Cost of unbilled performed x-ray imaging procedures / Year (FRW)	**6,671,700**
Cost of paper based request forms for x-ray examination (FRW)	**808,120**
Totals (FRW)	**531,695,035**

4.5. Purchasing plan for DICOM based PACS

4.5.1. Models of successful implementation of DICOM/PACS

For many health facilities, it can take years and much money to invest for a DICOM/PACS implementation. Among the different models of getting DICOM/PACS implemented as indicated in table 4.19, hospitals may consider these following to reduce the cost of successful implementation of DICOM/PACS: -Service contract meaning that the health facility purchases only service from the DICOM/PACS vendor; -Renting the technology where the health facility signs for a rental contract of the complete technology and -annual contract service where a health facility implements DICOM/PACS by paying for maintenance only.

Table 4.19: Models of successful implementation of DICOM/PACS

Models	Components of the model
1- Purchase and ownership of the technology	• Vendor technical support • Vendor service contract • Health care setting's technology system administration
2- Service contract	• Purchase a service from the vendor
3- Acquisition of the technology	• Responsibility • Ownership of the technology
4- Renting	• Rent of the complete technology
5-Annual contract service	• Maintenance only

*__Source:__ *Understanding financing options for PACS implementation*. *Purchasing strategies* (*46)*

4.5.2. Estimated price for DICOM/PACS installation

Pricing an installation of DICOM/PACS within a health facility can be difficult to find due to the price diversity depending on the brand, features, size area and needs of the health facility. Table 4.20 is presenting the estimated prices of DICOM/PACS provided by a health facility and the vendor. The Kodak vendor offers PACS/DICOM interfaced with RIS without any service at a price between FRW 687,000,000 - FRW 1,030,500,000 (US$ 1,000,000 - 1,500,000). For Orange Regional Medical Center (45), considered as a large 465 beds referral hospital similar with a large offer of specialized radiology services using DICOM/PACS standards, its DICOM/PACS installation cost was approximately FRW 1,305,300,000 (US$ 1,9 million); a maintenance service and on-site training inclusive.

Table 4.20: Estimated price for DICOM/PACS installation

Estimated price for DICOM/PACS installation				
Vendor	**Installation price**			
			US$	FRW
Kodak PACS/DICOM/RIS	PACS/DICOM/RIS		**1,000,000-1,500,000**	**687,000,000-1,030,500,000**
Health facility				
Orange Regional Medical Center (ORMC)	PACS		1,200,000	
	DICOM		400,000	
		Maintenance cost included (3years)	100,000x3	
			1,900,000	**1,305,300,000**

***Source:** *http://www.imagingeconomics.com* (45)

4.5.4. The estimated payback period

The table 4.21 refers to the estimated period of time required to get back the amount invested or expended on different radiology materials. An investment of FRW 1,305,300,000 on DICOM/PACS installation repaid by FRW 531,695,035/year (total sum of expenditures made within a year in radiology department) would have a payback period of 2.4 years.

Table 4.21: **Estimated payback period**

Estimated payback period	
Price estimates of DICOM/PACS installation	FRW 1,305,300,000 (US$ 1,900,000)
Total sum of expenditures made within a year in radiology department	FRW 531,695,035/year
Payback period lengthy estimate (year)	FRW 1,305,300,000 **/** FRW 531,695,035/year = **2.4**years

CHAPTER 5: DISCUSSION

A number of clinical, technical and financial issues have been collected on the benefits of integrating DICOM/PACS at CHUK. The findings would be applicable only on the hospital under study and may not be generalized to other hospitals of Rwanda. However, there were no studies on the subject of technical, financial and clinical cost benefits of integrating DICOM/PACS in Rwanda.

5.1. Technical benefits of integrating DICOM based PACS

After assessing the CHUK's radiology department usage, results in table 4.1 showed the presence of a considerable number of problems which have been described by different level of radiology staff were considered as factors reducing the quality of daily radiology activity performance and cost savings. The literature reported that the radiology staff which has been performing their daily tasks in a stress work environment lost the feeling of participating in the improvement of the radiology quality service delivery. On the other hand, the same literature described that the introduction of DICOM and PACS in the digital radiology system had improved work efficiency and productivity of radiology department (35). DICOM/PACS has advantages of processing improved reimbursements, reducing patient waiting time, solving the issue of medical x-ray image storage and archive, reducing report time of modality medical x-ray image results for patients looking radiology department services (36).

Considering the vendor diversity of digital x-ray imaging modalities and information system interfaces used at CHUK radiology department, as observed in table 4.2, the opportunity of adequate interoperability between various x-ray imaging modalities may appear impossible to happen. Therefore, as the majority of x-ray imaging modalities (4/8) are from the Siemens they can possibly be interoperable each other and be interfaced with the information technology systems (RIS and HER). The different digital x-ray imaging modality from different vendors also need DICOM/PACS interfaced with related information technology systems (RIS, HER, HL7) for facilitating the implementation of interoperability and the performance speed of x-ray imaging modalities.

Some literature reported that the diversity of digital medical imaging modalities and information technology system interfaces could not be an issue for their interoperability. The implementation of DICOM/PACS was advantageous solution to enable the interoperability between digital medical imaging modalities and their accessories such as imaging scanners, servers, workstations, printers and network hardware from various manufacturers (48). In addition, despite the available multivendor of medical x-ray imaging modalities, the hospital can possibly solve several challenges of interoperability, archiving, storage of medical x-ray images by integrating DICOM/HL7 based PACS because "DICOM is a cooperative standard to enhance interoperability and PACS can archive images for several years: 3-5 years is very common. This is both time and money saving benefits" (37).

However, we noticed that we had technically to understand the possibility of the interoperability and compatibility between medical imaging modalities and other systems. Before, medical imaging modalities were used to communicate with other modalities and equipments from the same vendor. Moreover the medical imaging modalities and accessories such as imaging printers and diagnostic image workstations needed to be from the same vendor if the data sharing was possible to be made. However, with the introduction of imaging communication standards (DICOM, HL7), modalities of different vendors can be compatible and communicate with each other within the radiology department, enabling an efficient imaging connectivity compatibilities and interoperability between imaging modalities and information systems (37).

5.1.1 Interoperability and compatibility of DICOM/PACS with old medical imaging equipments

Despite the multivendor setup observed on CHUK's radiology modalities, all the medical imaging modalities and accessories (scanners and printers) are DICOM/HL7/PACS compliant. "To make them communicate each other and share data, the interoperable standards' software of DICOM and HL7 are compatible to the structured hospital networked workstations using TCP/IP and to the running Microsoft windows 2000 operating systems. Furthermore, the interface between PACS ,EHR (Open clinic) and RIS is also compatible to allow a radiology department to store and maintain patients' imaging data, patient's demographic data registration, appointment scheduling (Open clinic), results entry and reports.

The radiology workstations are internet-enabled and can allow radiology technician and radiologists to access and exchange patient medical imaging information. They are equipped with dual flat screens in order to perform as medical diagnostic viewing workstation. An exception is in clinical wards where the computer apparatus has to be replaced or improved because it may not be digitally compatible with the medical imaging modalities and may not display medical images on its screen.

The network connectivity infrastructure (LAN and WAN) and a bandwidth required to implement the interoperability between medical imaging modalities are already there in CHUK. These networks can work on any browser like Firefox and Chrome and on any operating system like windows, Linux, android tablets and cell phones with browser.

Concerning the interoperability and compatibility between medical imaging modalities and the new DICOM/PACS system within and outside the radiology department, there will be no more particular components or features which will be needed depending on hospital specification needs.

5.2. Time duration

The time elapsed between x-ray exam order and patient arrival in x-ray examination room was remarkably extended. This was the case for the time duration between the patient's CT scan exam orders from surgery department to his arrival in CT scan examination room which was at the top (56 h 20 minutes) by comparing it to other time duration. Some reasons of this long time duration could be turnaround time for validation of CT scan exam order by the Director General of the hospital, lack of the request form of CT scan exam, long waiting of x-ray exam order scheduling and so on. Therefore, this extension of time duration between x-ray examination order and the arrival of the patient in x-ray examination room has an impact on the overall patient stay time in the hospital which increases accordingly. The issue was time saving between x-ray exam order and patient entry in x-ray examination room. In some literature, the implementation of immediate electronic x-ray exam order and electronic x-ray exam scheduling through HIS/RIS could possibly help to cope with the long time duration between x-ray exam orders to the patient's entry in x-ray exam room (38). There are several potential advantages of implementing DICOM/PACS standards and information technology systems (HIS, RIS) into a health facility such as an access to all health information on patients, easy x-ray exam orders and results availability and improved workflow which was the key to improve productivity and patient care (44).

The time spent in x-ray examination room appeared to be long for the patients consulting for various x-ray exam especially CT scan exams (75 minutes), followed by Fluoroscopy exam (50 minutes) and special radiography exams (42 minutes). A series of technical issues such as a disorganized radiology workflow management and radiology technologists' turnaround time for printing x-ray image results of the previous patient delay the beginning of the x-ray examination for the next patient who has already got in the x-ray examination room. Therefore, the patient may be at risk of exposure to x-ray radiations. Then, the implementation of DICOM/PACS could not only help radiology staff reducing the delay of patients in x-ray examination room by limiting radiology technologists' turnaround time and steps of processing x-ray examination, but it could also be taken as one of the security measure of minimizing risks of patient exposure to x-ray radiations.

The reported time duration to complete and to develop an x-ray image of various x-ray examination requests appeared to be long. The unexpected findings for time duration to complete an x-ray exam and to develop an x-ray image of a patient as shown on the figure 4.3 and figure 4.4 revealed that they were long: On the figure 4.3, a CT-scan medical x-ray exam was completed in 145 minutes; a special radiography x-ray exam completion was in 94 minutes and a general radiography was completed in 67 minutes. On the figure 4.4, the time duration made for CT-scan image development was 70 minutes, for the development of special radiography x-ray images was 34 minutes and 26 minutes for mammography x-ray image development. Therefore, these results appear to have an impact on the productivity of the radiology department. According to Lepanto L. (2003), the mean time to complete an x-ray examination in x-ray examination room based RIS/PACS/DICOM system has decreased from 14.0 to 7.4 minutes. The radiography film development was filmless and this step was absent. Then, Lepanto reported, in another study he carried, that the time of x-ray execution decreased up to 9 minutes 59 secondes for x-ray examinations which do not require much preparation. Then, the introduction of new technologies such as DICOM/PACS often improves time of x-ray image development and the time to complete x-ray exam (39).

Regarding the time of patient demographic data recording and radiologist reporting turnaround time, they appeared both elevated as indicated in table 4.4. The results showed that 1 h 32 minutes was the top time spent in patient demographic data recording of a patient consulting for general x-ray exam while on the other side 19 h 24 minutes was the highest time spent by radiologist to report a CT scan exam. The delay of patient demographic data recording has an impact on the timely availability of patient identification needed by cashier for billing before x-ray examination and it has also another effect on timely availability of patient for x-ray examination and healthcare delivery.

The failure of saving time while recording patient demographic data and reporting x-ray results can be apparently explained by a lack of use of hospital electronic health record (Open clinic) in the radiology department; paper based patient demographic data recording; the use of paper based x-ray report typing, copying and printing; report delivery delay to the radiologist for the signature, excessive radiologist workload and a remote single hospital reception desk for patient demographic data recording. The implementation of different information technology systems (RIS, HER, HL7..) can be manipulated with DICOM/PACS to minimize the time it takes to record patient demographic data and to save time spent by a radiologist during x-ray image reporting.

It was observed that the steps of distributing, viewing or handling other film related requests were taking long time duration and the time between two procedures of x-ray film processing was also high as indicated in the table 4.5. 5 h 25 minutes was the top time spent either for distributing, viewing or handling any other related CT scan x-ray results, followed by 2 h 18 minutes as time spent for distributing, viewing and handling general x-ray film results. The lack of x-ray imaging storage and archiving devices for faster and easier retrieval of x-ray film results could explain the existence of a long time for distributing, viewing or handling various x-ray film results. In addition, the study held in the University of California Davis health system reported that technical inefficient radiology workflow would be a reason of spending much time in searching and distributing medical imaging films. An example reported in this institution revealed that before the implementation of DICOM and PACS, radiologists, physicians and medical imaging technologists spent 1 to 3 hours searching for films daily and this were dissatisfied with radiology workflow system. Then, after the implementation of DICOM and PACS, this time decreased to 16 minutes (25). The benefit of the integration of DICOM/PACS standards interfaced with Information technology systems is that it may increase patients and healthcare providers' satisfaction and technically improve the radiology workflow.

The time between 2 x-ray film processing procedures also was high and this was remarkably observed for CT scan x-ray film results where 1 h 28 min was the time between 2 CT scan film result processing procedures. However, x-ray imaging processing steps of some x-ray exams were taking long time to be carried out.

The 29 h 26 minutes were found as the long approximate time patients consulting for CT scan examination spent in radiology department. The long time duration between 2 x-ray film processing procedures and the long time duration spent for distributing, viewing x-ray film results were part of the reasons responsible of the long patient waiting time in radiology department. The impact of these time durations may be observed on the patient health care delivery where patient x-ray image diagnosis delay to reach physicians for timely better healthcare management.

This waste of time while distributing, looking and handling other related film request and time between 2 modality medical x-ray films processing and approximate long time a patient spends in radiology department are good indication to the integration of the radiology standards such as DICOM/PACS interfaced with information technology systems (EHR, RIS, HIS..).

Considering radiology staffing shortage, the retention of radiology staff was a huge problem to monitor because radiologists and radiology technologists were leaving for high income jobs or jobs with less stress while there were not enough to enter. A number of 16 radiology staffs who are currently working in radiology department was reported insufficient according to the radiology workload and 5 more radiology staff were reported in need by the radiology department. This radiology staffing shortage is occurring at a time when the radiology workload volume is generally increasing. The different reasons mentioned above enlightened why the supply of a quick and quality radiology service delivery is insufficient to meet the standards.

However, a robust and innovative solution is the need of the hour to help to overcome the radiology staff shortage and streamline the x-ray image flow from referring physician-patient-radiology department to referring physician in order to improve the radiology workflow.
Then, the implementation of DICOM/PACS may help the hospital to address the issue of radiology staff shortage by improving the complex radiology workload and suppressing some steps from the radiology workflow issues such as removal of x-ray image jacket filling, x-ray image distribution and x-ray image quality checking.

The compliance was assessed on the use of modality medical x-ray image which was related to the use of x-ray image storage time, retrieval, archiving, security and backup storage taken as criteria of compliance conformity as illustrated in the table 4.7. A considerable number of criteria appeared not accommodating to the majority of x-ray imaging modalities except for CT scan modality which was compliant in using a small and limited CT scan image storage time, and the x-ray image storage device was available. Therefore, the security, storage, archive, retrieval and backup of patients' medical x-ray images were not implemented in radiology department of CHUK. The non compliance to the majority of criteria illustrated in table 4.7 explained a long workflow, lack of cost savings on consumables and difficulty of healthcare providers to obtain real-time access to patient x-ray images and its reports.

According to some literature, the integration of DICOM/PACS may be used to protect medical images and patient information in a system where only parties with permission can view or edit, to improve workflow, as well as cut costs (40). On the other hand, it was reported that the implementation of DICOM and PACS interfaced with RIS helped users to accelerate productivity by streamlining more efficiently x-ray images distribution, security, billing and workflow functionality (50).

Regarding the reporting format of x-ray image results, the paper based reporting format was dominant and disadvantageous for radiologists who couldn't get enough time to make a paper based report according to a queue of patients' x-ray results waiting for being reported. As evidenced by Marquez LO (2005), the implementation of DICOM/PACS may allow x-ray images stored in PACS to be vocally reported and reached the referring physicians via DICOM in the written form. Thus, it eliminates all manual processes of paper based reporting of x-ray image results. Still on the issue of the reporting format of patients' medical x-ray results, Marquez continued where he suggested that an additional technology to digital medical imaging system such as a robust introduction of PACS/RIS with voice reporting was essential to bring to an end the paper based format of reporting medical imaging results and as well decrease radiologist's report turnaround time (41).

5.3. Clinical benefits of integrating DICOM/PACS

Regarding the lookup time of x-ray results from clinical ward units to the radiology department, findings in the table 4.9 have proven that clinical staff which was running from clinical ward units to radiology department was wasting much time looking for various x-ray image results. In particular and on daily basis, 2 h 15 minutes was the longest fluoroscopy image results' lookup time for staff from internal medicine wards to radiology department; follow 2 h 01 minute considered also as a long turnaround time was for clinical staff moving from internal medicine wards to radiology department for special x-ray image results while 39 minutes were considered as the lowest turnaround time for clinical staff moving from pediatrics wards to radiology department looking for mammography x-ray image results.

These findings are important indicators showing how the CHUK clinical staff is seriously suffering from a waste of time in where they travel from their respective clinical department's ward to radiology department to look for modality medical x-ray results of hospitalized patients. Therefore, this long lookup time of x-ray image results has an impact on the quality of healthcare service delivery. The use of DICOM/PACS technology may avoid clinical staff turnaround time by running from their clinical ward unit to radiology department to look for patients' x-ray image results and it may also make fast and easy access to modality medical x-ray image results.

Regarding the reporting of x-ray image results by radiologists indicated in table 4.10, the results demonstrated that except a total of 100% of x-ray image results requested during medical ward round in pediatrics were reported while during the medical ward rounds in other clinical departments a considerable number of requested x-ray image results was not reported. This was supported by the case in clinical specialties wards where 60% of x-ray image results were not reported during the medical ward round, 65% of x-ray images results during surgical wards round were not reported. That presence of the high number of unreported x-ray results in the number of reported x-ray image results requested during medical ward round challenged physicians to make fast and right diagnostic decision and right patient's treatment. In this context, with the integration of DICOM/PACS technology the referring physicians will allow to access the reported x-ray image results requested during the medical ward rounds and will reduce delays on the diagnostic process.

5.4. Financial benefits of integrating DICOM/PACS

The high cost of radiology services or procedures and resources mentioned in this study were thought as an issue of loss. These later costs are unnecessarily increasing the hospital annual budget. The DICOM/PACS integrated with information technology systems may bring many financial benefits both to the radiology department and the hospital by eliminating costly radiology services and consumables. With the use of DICOM/PACS, the following list of financial losses may be avoidable per year: The cost of x-ray film results lost before the medical ward round which was estimated cost at FRW 294,069,915 (Table 4.11); the respective costs of x-ray films, x-ray consumables and personnel outside radiology with respective cost of FRW 97,690,019, FRW 7,693,825 and FRW 1,350,000 (Table 4.12); the average yearly cost of x-ray film results printed with errors which was estimated at FRW 2,476,825 (Table 4.13); the yearly cost of duplication of x-ray image results at FRW 62,661,375 (Table 4.14); the yearly cost of lost x-ray film results within radiology department estimated at FRW 56,912,625 (Table 4.15); the yearly cost of unbilled performed x-ray imaging procedures estimated at FRW 6,671,700 (Table 4.16); the cost of the disposal of radiology waste material estimated at FRW 1,360,631 (Table 4.17) and then the yearly cost of paper based request forms for x-ray exams for FRW 808,120 (Table 4.18). Therefore, the sum of the radiology department expenditures' costs reach per year an approximate amount of FRW 531,695,035. Even if all the financial challenges of radiology department were not listed in this study, an integration of DICOM/PACS technology in radiology department may help to improve cost savings and manage the productivity of radiology department.

5.5. Purchasing plan for DICOM based PACS

Inadequate budget has always been a central reason of DICOM/PACS project integration failure in many health facilities of the developing countries (45). And CHUK which is the main Rwandan referral hospital does not make an exception to this problem. Therefore, even if the implementation of DICOM/PACS is costly to hospitals, the financial, clinical and technical benefits increase to hospitals which cover for the DICOM/PACS implementation investment costs. In table 4-19, different models to obtain a successful implementation of DICOM/PACS were proposed in our study in order to lessen cost of the technology project implementation. Cleary in our experience, the models such as -service contract meaning that the health facility purchases only service from technology vendor, - renting of the technology where the health facility signs for a rental contract of the complete technology and -annual contract service where a health facility implements the technology by paying for maintenance only, could be adaptable to the budget problem of DICOM/PACS project implementation in case it happens.

But also new other solution was presented in order to acquire the costly project of DICOM/PACS implementation. Therefore, the yearly total cost of radiology department expenditures mentioned in our results can cover for this investment at the beginning and then after other different health stakeholders or government can support the investment. Evidence of our results has shown that the payback period could possibly be 2.4 years if we considered yearly total cost of expenditures against the global estimated cost of DICOM/PACS project implementation supported by one health facility from industrialized country. Despite the expensive cost of Orange Regional Medical Center's DICOM/PACS installation, this later was so interesting to be preferred because the important elements or features required during the implementation of DICOM/PACS were included in the overall package price supplied (continuing service maintenance contract, on-site training for radiologists and technical staff, migration of patients' data, larger servers for archive and storage, new workstations and monitors, DICOM/PACS software and future software updates).

But, significant challenges to acquire imaging standards technology in CHUK may occur. Here in this context of challenges, the hospital will identify the cost as the major barrier to adopt the DICOM/PACS integration, including initial and continuing costs of maintaining the systems.

Another important challenge may be concerning the human resources' low salaries, where the hospital has difficulty attracting and retaining IT staff to implement and maintain the DICOM/PACS use. The majority of healthcare providers of CHUK are generally less technologically proficient and more resistant to EHR; also may DICOM/PACS integration face the same challenge.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1. CONCLUSION

As a final evaluation based on the results found in this study, some conclusions can be made:

1. The results of our study demonstrated that technical challenges of radiology department reduced quality of healthcare delivery.

2. Convincing evidence has been collected relating to present clinical, financial and technical problems and risks before integration of DICOM based PACS at CHUK.

3. Indications has been provided that DICOM/PACS implementation interfaced with other information technology systems can clinically, financially, and technically improve a considerable number of x-ray imaging services provided by radiology department of CHUK.

4. The study results suggest that the integration of DICOM/PACS in the CHUK can at least improve technical efficiency related to efficient storage, processing, management and retrieval of patient x-ray images, tracking of patient x-ray image results and x-ray imaging procedure billing, quick x-ray image result reports and patient demographic data registration.

5. Adequate DICOM based PACS integration could overcome a number of financial challenges related to the high cost of x-ray films and consumables, loss of x-ray film results before medical ward round, duplicated x-ray images, erroneous prints of x-ray film results, unbilled performed x-ray imaging procedures, disposal of radiology waste materials and paper based request forms for x-ray exams. The findings revealed that these financial challenges were also a loss for the hospital.

We believe the results of our study showing the hypothesis saying that the integration of DICOM based PACS is clinically, technically and financially beneficial to CHUK can be accepted based on evaluations argued in the study. By answering the research question, our study showed that DICOM based PACS can play important role in the realization of the quality radiology department services delivery.

6.2. RECOMMENDATIONS

In the future, in case DICOM/PACS are integrated, commitments are needed from the ministry of health, CHUK and researchers to facilitate easier integration of ICT and other new technology systems in clinical and paraclinical fields. Based on our study findings, we recommend the following to:

6.2.1 The ministry of health:

- To provide financial and technical assistance to different level of healthcare settings' radiology department of Rwanda.
- To establish strategic context for medical imaging standards integration in referral hospital and district hospitals.
- To define supporting governance and process regarding the integration of imaging standards in healthcare settings.

6.2.2 The Kigali University Teaching Hospital (CHUK):

- To clearly understand the need and benefits of the integration of DICOM/PACS.
- To identify their own responsibilities and all tasks required during the planning, execution and closeout phases of the DICOM/PACS installation
- To look for adequate financial resources and technical assistance for successful implementation of DICOM/PACS project.

6.2.3 Researchers:

- To conduct a study assessing the impact of DICOM/PACS on radiology reporting turnaround time in district hospital of Rwanda.
- To conduct a clinical, technical and financial comparative study analysis between a pre and post DICOM/PACS implementation in referral hospital such as CHUK.

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APPENDICES

WORK PLAN FOR THE PROPOSAL

GANTT CHART

TASK TO BE PERFORMED	2013					2014							
	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Nov	Dec
1.1 Finalize Project 1.2 Project for submission.				x									
2. Ethical clearance and permission to do the work						x							
3. Community contact to orient members on project.			xx										
4. Pre-testing and finalizing research instruments e.g. questionnaires				x									
5. Data Collection (Fieldwork)							x	xx	x				
6. Data coding, and entry into computer								x					
7. Data analysis									xx	xx			
8. Project Writing (first draft)											xx		
9. Project Presentation Workshop												x	
10. Project Writing (Final draft)												x	
11. Submission of Final Report													x
12. Feedback to the community													x

BUDGET

I. Preparation for the study

Nº	Item	No. of Persons	No. of Days	No. Person-days	Cost/Unit (FRW)	Total FRW
1	Project Presentation Workshop	30	1	2	0	400,000
2	Research team organization	2	3	2	5,000	30,000
	Sub-total 1					**430,000** FRW

II. The survey

Nº	Item	Persons/Materials	No. of days	Person-Days	Unit Cost (FRW)	Total (FRW)
1	Library, electronic and other research	-	-	-	-	131,585FRW
2	Typesetting, Printing, Photocopy and Binding of Questionnaire.	1	1	1	-	25,200FRW
3	Transport and Perdiem for data collector and entry	2	4	8	5,500FRW	22,000FRW
	Sub-total 2					**178,785 FRW**

III. Study supplies

No	Item	Quantity	Unit Price FRW	Total FRW
1	PC	1	350,000	350,000
2	AIR Tel internet connection modem	1	20,000/month	180,000
3	Reams of papers	5	3,500	17,500
4	SPSS software	1	250,000	250,000
5	Communication	10 mtn, Airtel	5,000	50,000
6	Bloc notes	5	700	3,500
8	Pencil	5	100	500
9	Pen	15	100	1,500
10	Eraser	3	200	600
11	Bag	1	10,000	10,000
	Sub – total 3			**893,600 FRW**

IV. Production of the report

No	Item	Quantity	No. of days	Pers.-days	Unit Price FRW	Total FRW
1	Crosscheck & Verification of data	1	3	3	0	0
2	Entering Data	1	4	1	5,000	20,000
3	Analysis of Data	1	4	1	10,000	40,000
4	Report (Draft 1-3)	1	8	8	10,000	100,000
	Sub – total 4					**160,000 FRW**

V. Workshop for report validation

No	Item	Quantity	NO./Days	Pers-days	Unit Price FRW	Total FRW
1	Conference Room	60	1	60	300,000	300,000
2	Projector	1	1	-	25,000	25,000
3	Bloc notes + Pens	50+50	1	50		25,000+1,500 =26,500
	Sub–total 5					**351,500 FRW**

BUDGET SUMMARY

Nº	DESCRIPTION	TOTAL/FRW
1	Preparation for the Study	430,000
2.	The survey	175,785
3	Study supplies	893,600
4.	Production of the Report	160,000
5	Workshop for report validation	351,500
	TOTAL BUDGET	**2,010,885 FRW**

ANNEXES

Annexe 1: INFORMED CONSENT FORM

A. Explanation

Dear Respondent,

My name is MARARA Alpha-Arsene and I am student pursuing a Masters degree in Health Informatics at College of Medicine and Health Sciences. My work place is at Kigali University Teaching Hospital. This questionnaire is designed to carry out on the topic:***A TECHNICAL, FINANCIAL AND CLINICAL COST BENEFIT ANALYSIS OF INTEGRATING A DICOM BASED PACS AT THE CHUK.***

I need your support by helping me to answer this questionnaire. The information given shall be used purely for an academic purpose with a high degree of confidentiality. Feel free therefore to give your views and opinions on this subject of investigation.

Your participation in this study will be voluntary and should you choose not to be included. If you agree to be included in this study, please sign the section below.

B. Consent

I ...., confirm that the purpose of this study and my role have been well explained to me by Mr MARARA Alpha Arsene. I agree to the conditions explained and give consent to be included, or for .... who is my dependant by virtue of being a minor or unable to consent.

Sign........................

ID No...................

Date.............................

Thank you.

Contact: MARARA Alpha-Arsene

Phone: +250788649898

Email: malphaarsene@yahoo.fr

REQUEST FOR PERMISSION TO DO RESEARCH

University of Rwanda

College of Medicine and Health Sciences

P.O. Box: 3286 Kigali – Rwanda
Tel: (250) 25257188 ; (250) 788665979
Fax: (250) 571787
E-mail: info@khi.ac.rw

Directorate of Postgraduate Studies

Kigali, on 29/01/2014

N° 13/UR-CMHS /DPGS/14

TO WHOM IT MAY CONCERN

SUBJECT: REQUEST FOR PERSMISSION TO DO RESERCH IN YOUR INSTITUTION

In the process of fulfilling the partial requirement for the award of Master of Science in Health Informatics students are required to write a dissertation in their area of study. In that regard, **MARARA Alpha-Arsene** has been granted ethical clearance to conduct a study entitled ***"A TECHNICAL, FINANCIAL AND CLINICAL COST BENEFIT ANALYSIS OF INTEGRATING A DICOM BASED PACS AT THE KIGALI UNIVERSITY TEACHING HOSPITAL"***

I will therefore highly appreciate if you could allow the student to conduct the study in your institution.

Thank you in advance for your assistance.

Prof Kato J. NJUNWA
Director of Postgraduate Studies

CC:

- Mr Ngenzi Joseph Lune, IT Coordinator E-Health Centre of Excellence, College of Medicine and Health Sciences, University of Rwanda

PERMISSION TO DO RESEARCH IN CHUK

C.H.U.
Quality Health Care
Training & Research

CENTRE HOSPITALIER UNIVERSITAIRE
UNIVERSITY TEACHING HOSPITAL

Ethics Committee / Comité d'éthique

February 19, 2014 **Ref.: EC/CHUK/019/14**

Review Approval Notice

Dear **Alpha-Arsene Marara,**

Your research project: ***"A technical, financial and clinical cost benefit analysis of integrating a DICOM based PACS at Kigali University Teaching Hospital"***

During the meeting of the Ethics Committee of Kigali University Teaching Hospital (KUTH) that was held on 19/2/2014 to evaluate your protocol of the above mentioned research project, we are pleased to inform you that the Ethics Committee/CHUK has approved your protocol.
You are required to present the results of your study to KUTH Ethics Committee before publication.

PS: Please note that the present approval is valid for 12 months.

Yours sincerely,

DR. STEPHEN RULISA
HEAD - DEPARTMENT OF CLINICAL RESEARCH
CHUK

Dr. Stephen Rulisa
The President, Ethics Committee,
Kigali University Teaching Hospital

<<University teaching hospital of Kigali Ethics committee operates according to standard operating procedures (Sops) which are updated on an annual basis and in compliance with GCP and Ethics guidelines and regulations>

B.P. :655 Kigali- RWANDA Tél. Fax : 00 (250) 576638E-mail : chuk.hospital@chukigali.org

Annexe 2: DATA COLLECTION INSTRUMENT/QUESTIONNAIRE

Code ....

A TECHNICAL, FINANCIAL AND CLINICAL COST BENEFIT ANALYSIS OF INTEGRATING A DICOM BASED PACS AT THE CHUK

This tool is composed by questions about the cost benefits of the integration of DICOM/PACS and other related technologies contributing to enhance the storage, archiving, retrieving, the productivity and exchange of medical data images and cost reimbursement

QUESTIONS:

Questions focusing on technical and clinical reasons of integrating DICOM based PACS and answered by a Radiology staff.

1. Which are the existing problems you encounter in your daily professional activities within radiology department?

2. What are the available digital modalities being used in the radiology department?

3. What are the kinds of digital radiology modalities vendors you use in the department?

4. In the CHUK Radiology Department, is there any use of

   a. DICOM system? Yes/No
   b. PACS system? Yes/No
   c. HL7 system? Yes/No
   d. Unique hospital wide patient identification? Yes/No
   e. Radiology Information System? Yes/No
   f. Hospital Information System? Yes/No

5. Do you know how much time passes between a patient modality medical x-ray image request and the patient arrival in exam room?

6. Do you know how much time of a patient spends in the exam room?

7. Do you know the time a modality medical x-ray exam is completed?

8. Do you know the time made to develop modality medical x-ray image?

9. Do you know the length of time for the radiology technician to record patient demographic data?

10. Do you know the report turnaround time for the radiologist to avail the complete patient modality medical x-ray image result?

11. How many hours does a technologist spend for distributing films, viewing and handling other films related requests?

12. Do you know the time duration between two modality medical x-ray image printings?

13. Do you know the approximate total of time a patient can pass in the x-ray radiology department?

14. What is actually the approximate maximum time duration of electronic image storage?

15. Do you have an electronic image archiving system?

16.Are there any security issues related to patient's printed images handling today?

17. Do you suffer from radiology staff shortage in your department?

18. How many X-ray film printers do you use in your department?

19. In which form the report or interpretation of patient's modality medical x-ray image result is made?

20. What is the average time between an imaging request is made by the clinician and the moment the exam is performed?

21. A clinical researcher or any other kind of healthcare provider may arrive at CHUK for patient data collection including a review of patient x-rays and some patients had been discharged long ago and left with their x-rays. In this instance, is it easy for the department to retrieve patient x-

ray data records for him in order to review the patient health history or to share a meaningful educative experience?

22. Do you have enough image storage modalities?

23. Where do you store images for meeting future needs (backups, research purpose)?

24. Do you have any idea of a daily turnaround time duration of a clinical staff moving from his ward unit to radiology department looking for modality medical x- ray results of hospitalized patients.

Questions focusing on financial reasons of integrating DICOM based PACS and answered by a finance and administrative staff

25. What is a yearly estimated total cost expenditure of modality medical x-ray image processing?

26. The total annual number of erroneous prints or unusable films............ and the cost....

27. The number of duplicate x-ray image results requested per day........../ cost......

28. The number of lost X-ray film results per day before being delivered to their patient ..../cost.......?

29. How many unbilled imaging procedures are performed /cost.....?

30. The cost of disposal of radiology waste materials.................?

31. The cost of paper based request forms for x-ray exams.............?

32. What can be the good models to be used in order to get in hands a successful installation or implementation of DICOM/PACS?

33. What could be an estimated price of installing DICOM/PACS in health care setting.....?

34. What could be an estimated payback period for DICOM/PACS integration............?