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Clinicians' perspective of pacs at Charlotte Maxeke Johannesburg Academic Hospital

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CLINICIANS' PERSPECTIVE OF PACS AT CHARLOTTE MAXEKE JOHANNESBURG ACADEMIC HOSPITAL

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A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, partial in fulfilment of the requirements for the degree of Masters of Medicine in Diagnostic Radiology.

Johannesburg, 2023.

Declaration

I, Polite Tshalibe (Student Number 1738675), declare that this research thesis is my own work. It is being submitted for the degree of Masters in Medicine (Diagnostic Radiology) at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any other degree or examination to this or any other University.

DR POLITE TSHALIBE



On this 14th day of June 2023

Dedication

I dedicate this Research Thesis to my supporting wife, Nontokozo, and my two beautiful children, Lungile and Siyanda.

Publications and presentations

This has been published in the South African Journal of Radiology, which is a PUBMED Indexed journal.

The citation for the published article is:

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Abstract

Background:

Picture archiving and communication systems (PACS) are now an established means of capturing, storing, distribution and viewing of all radiology images. The study was conducted in a quaternary hospital, Charlotte Maxeke Johannesburg Academic Hospital (CMJAH), part of University of Witwatersrand teaching circuit, in South Africa. There are few studies conducted in our local environment evaluating the clinicians' perception of PACS in public teaching hospitals.

Objectives:

To measure the clinicians' perceived benefits and challenges of PACS.
To document their perceived views on how the current PACS can be improved.

Methods

This was a cross-sectional observational study over a period of five months, from September 2021 to January 2022, carried out at CMJAH. Questionnaires were distributed to clinicians with PACS experience. Descriptive statistics were conducted. Categorical variables were presented as frequencies and percentages. The continuous variables were presented as mean ± standard deviation.

Results:

The response rate was 54%. The survey found the benefits most reported by clinicians were improved patient care, less time needed to review an exam, improved image comparison, and consultation efficiency. With respect to perceived challenges, the unavailability of images at the bedside, problems with access, and a lack of advanced image manipulating software were noted most frequently. The most frequent recommendations for improvements focused on the aforementioned challenges.

Conclusion:

Although a small majority of respondents found PACS beneficial, there were also significant issues with accessibility and functionality of the system.

Contribution:

The findings will assist in future hospital or provincial-wide PACS deployment projects.

Acknowledgements

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Table of Contents

Declaration ii
Publications and presentations iv
Abstract v
Acknowledgements vi
Table of Contents vii
List of Figures ix
List of Tables x
List of Abbreviations and Terminology xi
1. Introduction 1
1.1 Rationale for this study 1
1.2. Picture Archiving and Communication Systems (PACS) history 2
1.3. What PACS Is 3
1.4 Benefits of PACS 3
1.4.1 Patient care 3
1.4.2. Increased Productivity 4
1.4.3 Improved management of resources 4
1.4.4. Improved interpretation 5
1.4.5. Additional benefits 5
1.5. Challenges of PACS 5
1.6. Aims and objectives 7
1.6.1. Study aim 7
1.6.2 Study objectives 7
2. Materials and Methods 8
2.1. Research paradigm 8
2.2. Sample 8
2.2.1. Inclusion and exclusion criteria 8
2.2.2. Background of PACS implementation at CMJAH. 8
2.3. Study instruments 13
2.4. Data collection 14
2.5. Data analysis and statistics 14
2.5.2 Open ended questions 16
2.5.2. Data management 16

2.5.3 Statistical analysis 17
2.6. Ethics 17
3. Results 18
3.1. Classification of level of agreement 18
3.2. Classification of percentage of agreement 18
3.3 Survey response summary: 18
3.4 Questionnaire reliability 19
3.5. Demographics 20
3.6. Survey Results 22
3.7.1. Perceived benefits: 25
3.7.2. Perceived challenges 26
3.8. Open ended questions: 28
3.8.1. Benefits and challenges: 28
3.8.2. Recommended improvements: 30
4. Discussion 32
4.1. Perceived benefits of PACS 32
4.1.1. Time to review exams and ease of access to exams 32
4.1.2. Patient Care and service delivery: 32
4.1.3. Reduced hospital length of stay: 33
4.1.4. Consultation with other clinicians and impact on efficiency 34
4.1.5. Impact on academic teaching: 35
4.2. Perceived challenges 35
4.2.1. PACS access 35
4.2.2. Image quality & performance (speed) 36
4.2.3. System support and training: 36
4.3 Improvements 37
4.4. Limitations of the current study 39
4.5. Implications of findings and future applications 40
5. Conclusion 42
6) References 43
Appendix A: Ethics Clearance Certificate 46
Appendix B: PACS opinion survey questionnaire. 47
Appendix C: Participant information form 51

Appendix D: Consent form 53
Appendix E: Benefits and challenges statements response distribution 54
Appendix D: Note on referencing style 60

List of Figures

Figure 3.1. Distribution of clinicians by speciality. 20
Figure 3.2: Participant's distribution according to position held and specialty 21
Figure 3.3. Chart of participants' years of PACS experience. 22
Figure 3.4: Word cloud graph of positive comments. 29
Figure 3.5: Word cloud graph of negative comments. 30

List of Tables

Table 3.1: Perceived benefits questions reliability tests. 19
Table 3.2: Perceived challenges statement reliability test. 20
Table 3.3: PACS survey results. 23
Table 3.4. Perceived benefits of PACS survey results. 24
Table 3.5. Perceived challenges survey results: 27
Table 3.6: Summary of open ended question comments. 28
Table 3.7: Proposed recommendations for PACS improvement. 31

List of Abbreviations and Terminology

3D	Three dimensional.
ALARA	As Low As Reasonable Achievable
CD	Compact Disc
CHBAH	Chris Hani Baragwanath Academic Hospital.
CMJAH	Charlotte Maxeke Johannesburg Academic Hospital
COVID	Coronavirus Disease
CT	Computed Tomography
DICOM	Digital Imaging and Communications in Medicine
ECHO	Echocardiogram
ECG	Electrocardiogram
EMR	Electronic Medical Record
HIS	Hospital Information System
HJH	Helen Joseph Hospital
IT	Information Technology
KTH	Klerksdorp/ Tshepong Hospital
LODOX	Low-dose X-ray
MIP	Maximum Intensity Projection
MPR	Multi-planar Reformation
MRI	Magnetic Resonance Imaging
PACS	Picture Archiving and Communication Systems
POPIA	Protection Of Personal Information Act
RIS	Radiology Information System
RHMCH	Rahima Moosa Mother and Child Hospital
SAJR	South African Journal of Radiology
SD	Standard Deviation
TMRH	Thelle Mogoerane Regional Hospital
UPS	Uninterrupted Power Supply.
VPN	Virtual Private Network

1. Introduction

1.1 Rationale for this study

Picture Archiving and Communication Systems (PACS) are now a recognised means of digital image acquisition, archiving, distribution, and viewing (1). The technology is unique in that it delivers the radiology reports and exams to the medical practitioner right at the point of care (2).

Extensive research has been done to assess if PACS has attained its main objectives of improving patient care and efficiency within health care systems. Most of these studies have been focused on their approaches, with most assessing workflow impact, patient outcomes and cost-saving, with indeterminate outcomes (3-9). The majority of research studies have placed much emphasis on how PACS affects radiology department workflow efficiency (3-6).

Many studies have been conducted to evaluate PACS post-implementation. Most of these studies were conducted in America, Europe, and Asia. These studies have been more focused on approach, and with different objectives. For instance, there are studies on users' satisfaction (1, 10), PACS acceptance (11), cost-effectiveness (12) and PACS pre- and post implementation (13).

In the past four decades, PACS has evolved, became more established, and been integrated into clinical units. However, the following questions have arisen and received less research attention: How high is the clinicians' acceptance of the system? What improvements can be made to the currently existing system? What conclusions can be drawn from previous PACS installations that could assist in future PACS deployments? (14). Has PACS only digitised and automated the process of healthcare imaging, or has it improved clinical work practice? (2).

In our local environment in South Africa, Schoeman and Mostert-Phipps (15) conducted a survey based study on referring physicians' perspectives of PACS, this study concentrated on referring physicians with private consulting rooms at three private hospitals in Port Elizabeth. Moodley, S, and Moodley, I (12) conducted a comparative cost analysis of PACS versus analog radiography in private practice.

It has been well documented in literature that hospital staff do not easily accept new technology unless they understand and embrace it fully (16). To date, there are limited studies in our local environment in South Africa investigating the end user views about the PACS in public teaching hospitals. The purpose of the current study is to access the benefits and challenges realised by clinicians from PACS at Charlotte Maxeke Johannesburg Academic Hospital (CMJAH) six years post-implementation of the system. In addition, their views on how the system can be improved will be documented.

1.2. Picture Archiving and Communication Systems (PACS) history

Picture Archiving and Communication System (PACS) offer the chance to do away with film based imaging (2, 13). Hard copy film was once the only method of capturing, storing, and viewing of medical images. In the 1970s, the concepts of PACS was born in Europe, however, it was not until the early 1980s that the first PACS system was established in the United States at the Universities of Pennsylvania, California Los Angeles (UCLA), and Kansas City (17). In the 1980s, a few less effective PACS deployments occurred across Europe. In London's Hammersmith Hospital, in the 1990s, PACS became a hospital wide technology (1). Large-scale PACS initiatives covering a number of provincial health institutions have been

developed, for example, in a provincial PACS implementation in Canada (13). The first experimental PACS installation in Asia was in Japan in 1984 at Osaka University followed by the first practical PACS installation in 1989 at Hokkaido University (18).

The last few years have seen a tremendous increase in the adoption of PACS in most radiology departments in South Africa. PACS adoption in South Africa began primarily in the private sector; however, the public sector implementation of PACS has significantly lagged behind because of a lack of funding (12). Most public sector hospitals have small PACS systems limited to radiology departments. CMJAH implemented a PACS for the entire hospital in 2016.

1.3. What PACS Is

It is a group of image acquisition devices, connected to an archive and display systems that enable the transfer and display of digital images at various locations (19, 20). This system assists the radiology department in providing exams and reports to radiologists and medical practitioners. This system comprises relevant hardware and software. The hardware component consists of imaging machines, networks, servers, archives, and workstations. The software is responsible for image storage, distribution across the network, image viewing, and manipulation at work or review stations (20).

1.4 Benefits of PACS

1.4.1 Patient care

Schulze et al. (21) cited that PACS improved patient care. Though previous studies have proved this to be a difficult factor to quantify (2), in their argument they state that if there is an improvement in comparison to previous imaging, this leads to faster clinical decision making, hence reducing hospital stay and less need for repeat imaging hence a reduction in unnecessary radiation dose. Watkin JR et al (8) looked into how PACS and other factors impacted how long patients with total hip and knee arthroplasty stayed in the hospital. There was an apparent reduction of 25% in the hospital length of stay for total knee arthroplasty patients, with no significant reduction for total hip replacement patients.

1.4.2. Increased Productivity

Reducing the number of repeat studies will increase productivity in the Radiology Department (7, 19, 21). Reduced time spent performing a study increases patient throughput, this is achieved as a result of eliminating manual film processing. Electronic ordering, which is much faster than manual ordering, can eliminate time spent doing administrative work (7, 21). There is a reduction in time for images to be available for interpretation and for the report to be sent out to the clinician (13, 19, 21).
Improved professional consultation between onsite radiologist-clinician and offsite radiologists can expedite clinical decision making and patient management. These consultations can reduce the number of patients transfer from one center to another (13). A clinician could make better use of time by not having to walk to the radiology section to review studies and discuss patient bookings.

1.4.3 Improved management of resources

The patient who is the subject of the radiological examination can have their progress monitored and tracked by their clinicians. Within the radiology department, workload

distribution can be prioritised and quality control can be performed to assess the productivity of radiologists and radiographers (21).

1.4.4. Improved interpretation

The radiologist will experience improved interpretation due to less administrative work, advanced hanging tools for image manipulation, an improved working environment with fewer frustrations, and better decision support applications available on workstations (5, 9, 21).

1.4.5. Additional benefits

A large data archived and ease of retrieval of the information leads to enhanced teaching and research (13, 21-23). Furthermore, the biggest benefit is the multisite distribution of images compared to analogue radiography, which is only available in one place (9).

1.5. Challenges of PACS

In the united kingdom National health Services (NHS) Singh et al (24) evaluated the advantages and problems of digital imaging. They highlighted the problem of poor image quality on image review stations located in wards and clinics, and image transfer to other hospitals was a challenge.

MacDonald et al. (13) assessed the pre and post implementation of a provisional PACS in Canada. They concluded that the main disadvantage of PACS from a clinical perspective was reduced interaction between radiologists and clinicians. From an administrative side, it was costly to implement PACS, resulting in more costs per exam. However, capital costs are no longer an issue today as the prices of PACS implementation have come down. The other

downside of PACS is system vulnerability to crashing and poor reliability. Despite these concerns, PACS implementation has steadily increased throughout the world.

1.6. Aims and objectives

1.6.1. Study aim

The aims of this study is to evaluate the clinicians' perceptions of PACS at CMJAH as well as their views on how the PACS system can be improved.

1.6.2 Study objectives

Primary Objective

- To measure clinicians' perceived PACS benefits and challenges.

Secondary Objective

- To document their perceived views on how the current PACS can be improved.

2. Materials and Methods

2.1. Research paradigm

This was a mixed methods study, using both quantitative and qualitative research methods based on a questionnaire survey.

2.2. Sample

A sample size of 375 was calculated with the open source epidemiologic statistics calculator for public health (25) using a power of 80% at 0.05 alpha with a 95% confidence interval. Convenience sampling of the survey population working at Charlotte Maxeke Johannesburg Academic Hospital (CMJAH).

2.2.1. Inclusion and exclusion criteria

The study population included referring doctors from different specialities who routinely referred patients to the radiology department for imaging. Interns, medical officers, registrars and consultants were among them. Further included were the registrars who had rotated through CMJAH from other university circuit hospitals. Radiologists and radiology registrars were excluded. Questionnaires with incomplete responses on section of PACS environment and demographics.

2.2.2. Background of PACS implementation at CMJAH.

CMJAH is a quaternary hospital located in Parktown, Johannesburg (Gauteng province, South Africa). It is part of the six major Witwatersrand University circuit hospitals. The other 5

hospitals include Helen Joseph Hospital (HJH), Rahima Moosa Mother & Child Hospital (RMMCH), Chris Hani Baragwanath Academic Hospital (CHBAH), Thelle Mogoerane Regional Hospital (TMRH), and the Klerksdorp/Tshepong Hospital (KTH). CMJAH is equipped with one MRI (1.5 Tesla) and three computed tomography (CT) scanners. The total number of ceiling-mounted X-ray machines is 14, of which four are mounted in the casualty department, two in block 5 (medical), two in the orthopaedic unit, four in the radiology department catering to adult patients, and two in the pediatric radiology unit. There are three fluoroscopy machines dedicated to adult screening cases and one fluoroscopy machine in the pediatric radiology unit. The radiology intervention unit there has two fluoroscopy machines, one is a biplane angiography system, and the other is a standard screening fluoroscopy machine. The mammography unit has one digital mammography machine. There is one LODOX (low-dose X-ray) machine at the casualty trauma unit capable of providing full-body X-ray images in a few seconds. The hospital has a total of eight portable x-ray machines and seven C-arm fluoroscopy machines.

Picture archiving and communication systems (PACS) were implemented in 2016. A robust, high-end fourth generation system was set up by the Philips vendor. This system connects to workstations via the web interface and runs on a local area network (LAN). To meet the demand of data traffic across the network, the speed of data transfer is up to gigabits per second.

The PACS system is capable of connecting mobile devices via wireless connection to hospital Wi-Fi. These portable devices need to be configured by the I.T (Information Technology) department first before they can access PACS through the web interface. O'Connel and Patlas (26) in their commentary article on "Mobile devices and their prospective future in emergency

radiology' suggest the use of mobile devices for study interpretation is great for enabling studies from anywhere, anytime, and may be suitable for clinicians at the bedside.

This PACS system is interfaced to the RIS (Radiology Information Systems) and HIS (Hospital Information System). In addition, it interfaces with the nuclear medicine department. At the time of writing, the following modalities were not connected to PACS. The list includes surgical theatre C-arm fluoroscopy and cardiology angiography machines; hence, the images from these modalities cannot be archived. According to PACS administrators, this has to do with the machine DICOM licenses that have to be bought from the vendors, and some machines have hardware that is incompatible with the current generation of PACS.

At installation, the PACS system had a local site archive and a backup offsite archive. Both of these were connected via VPN (virtual private network). Unfortunately, the offsite backup archive was burned down during a fire hazard that ravaged the building in 2017. At the time of writing, there was no backup archive. The cheaper solution is investment in a cloud based PACS, which offers compelling benefits that include diversified disaster recovery, predictable expenditure (pay per study), reliable archiving, flexible growth, and continuous technology upgrades. Cloud services transfer the responsibility for software and hardware upgrades, security measures, and most functional aspects to the service provider (27).

CMJAH has the following referral hospitals: Bertha Gxowa, Far East Rand, Tambo Memorial, Edenvale, and Pholosong. The following hospitals are linked to CMJAH PACS: Bertha Gxowa, Far East Rand, Sizwe, and Pholosong Hospitals. At the time of writing, efforts were being made to connect Leratong Hospital, Helen Joseph Hospital, and Yusuf Dadoo Hospital. The downside of this connectivity is that only CMJAH is able to access studies from the connected hospitals.

Clinicians from referring hospitals are unable to view studies and reports from the CMJAH PACS system. This has a cost disadvantage because hard copy films have to be printed and sent back along with the patient. In addition, the number of repeat studies is high for most referred patients because either the images or reports may not be available at that critical time when clinical decision making may be dependent on imaging. All these are detrimental to patient management and result in unnecessary radiation exposure, which is against the ALARA (as low as reasonably achievable) principle.

The total estimated cost of PACS implementation was close to R50 million. The vendor has an ongoing contract to service the system. At initial setup, it was considered that image quality was of paramount importance for the end user reviewing images. A total of close to 40 desktop computers along with 19-inch flat panel viewing monitors were given out to critical areas in the hospital, which included wards and clinics. These monitors had screen resolutions of 1.5 megapixels. A total of 12 diagnostic workstations were distributed to the radiology department. A typical radiology diagnostic work station comprises a personal computer with two diagnostic gray scale viewing monitors and a small standard viewing color monitor with access to the RIS (Radiology Information System). The diagnostic monitors have a screen resolution of 3 megapixels. However, the workstation for mammography has 5-megapixel grayscale monitors with a high calibrated luminance of at least 500 candelas. The radiology report is generated from RIS in two ways: either by hand typing or by voice detection.

In surgical operating rooms, workstations with wall-mounted 40 inch monitors were installed in order for the surgeons to have access to PACS and review images prior to or during the performance of surgical procedures. Some of these monitors were stolen from their mounting sites. It is worth mentioning that despite this set up, the old viewing boxes are still present in

most operating rooms, as they may still be necessary for those clinicians who prefer to review hard copy images, and they are a backup when PACS is down.

Despite the intended purpose of PACS, which is to eliminate film based technology and go 'filmless', the hospital still prints films for those patients referred from satellite hospitals. Films are also printed during PACS downtime, as most clinicians will need to review images prior to making clinical decisions critical to patient management. This is one of the reasons why the viewing boxes were not completely eliminated. In addition, some patients sent from satellite hospitals come with film packets, which will need to be viewed on a viewing box.

Prior to PACS implementation, the radiology department would archive CT and MRI studies on discs. Post PACS implementation, archiving of these studies was only done for all those patients who came for follow up imaging. It was apparent that archiving the entire CD archive would overburden the storage space as some of the patients may have died and some may have transferred to other hospitals. Thus, old studies were archived as patients came for follow-up imaging. An attempt was also made at the Mammography Department to digitise hard copy films of those patients coming for follow up or routine screening mammography. The PACS administrators do not recall receiving any special requests from clinicians to archive some of the images from film packets for future reference.

It has been noted in several studies that new technology is not readily adopted by hospital staff unless they completely comprehend and embrace it (16). Post-PACS implementation training workshops were conducted to familiarize clinicians and radiology staff with this new technology. When new interns join the hospital, such workshops are conducted. These PACS training courses are conducted twice a year, and the training course runs over a full day.

During training, all clinicians are given unique log in credentials to access the PACS system. However, it was highlighted by the PACS administrators that the turnout for the PACS training has generally been poor. In order to accommodate those clinicians with no login credentials to access PACS, log-in credentials unique to the wards and clinics were created. This poses a security threat as unintended users may have access to PACS.

A few unintended consequences of PACS implementation resulted in some staff members who used to work in dark rooms being re-allocated to do other jobs, for example, as cleaners and clerks.

2.3. Study instruments

A questionnaire used by G.J Jorwekar et al (1) was be adopted and modified to suit our local environment. The questionnaire is attached in Appendix B. For most statements, comments were sought using a categorical method and a four point Likert scale. The questionnaire had several statements about perceived benefits and drawbacks of PACS that the respondents were asked to rate. Participants were invited to assign a score between 1 and 5; 1 (strongly disagree) to 4 (strongly agree) and 5 (Neutral).

The survey questionnaire first section captured data on the participants' environment and demographics; the second section inquired about the perceived PACS advantages, and the third section acquired data on perceived PACS drawbacks. An opportunity to include general comments was provided by an open-ended questions at the end of the questionnaire.

2.4. Data collection

Data collection was done during a five month period from September 2021- January 2022. Two complementary methods of questionnaire distribution were adopted: through an online survey and hardcopies. The researcher employed the help of the department secretaries to distribute the survey link via e-mail to participants attending virtual meetings. An opportunity to present the study was given to the researcher at the end of the virtual meetings. Participants were given 20 minutes to complete the questionnaire, after which the online survey was closed.

Hard-copy survey questionnaires were distributed to participants who held in person clinical meetings. At the end of the clinical meeting, participants were introduced to the study and given time to complete the questionnaire. To encourage clinicians to respond, the questionnaire was anonymous. There were no personal identifiers captured on the questionnaire.

In both cases a participant information and consent sheets were distributed along with survey questionnaires. The participant's information and consent form are attached as Appendix B and C respectively. For the online survey, data was collected on Microsoft Forms.

2.5. Data analysis and statistics

2.5.1 Survey questionnaires

Data from the data collections sheets was entered into a Microsoft excel spreadsheet. This data was imported into STATA Version 15 (Stata Corp) for further analysis. Descriptive statistics was then conducted.

Data were grouped into categorical and continuous groups. Where the continuous variables were not normally distributed, they were reported as mean, standard deviation, or median and interquartile range. Missing information was checked on each variable. Association between categorical variables was evaluated using the Pearson's Chi-Square or Fisher exact test. Pearson's correlation was done, and Cronbach alpha was used to check reliability and validity of the questions.

For Chi-Square/Fisher Exact tests, if the resulting p-value was < 0.05 we rejected the null hypothesis (Ho) and accepted the alternative hypothesis (Ha). An example of hypothesis testing employed in the analysis is as follows:

Ho: Clinicians' perception that PACS will reduce the time needed to review an exam and the position held are independent;

Versus

Ha: Clinicians' perception that PACS will reduce the time needed to review an exam and the position held is not independent

2.5.2 Open ended questions

The open-ended question was examined using a content analysis technique that counts the frequency with which specific characteristics appear in written texts. In content analysis, the following four coding units are typical: a single word, a group of words, a phrase, or a theme. Two coding units were used in this study's analysis of the open-ended question: words and themes. Within the context of the study, words and themes were classified into one of two distinct groups (benefits or challenges), and then these groups were further subdivided. For example, a benefit of PACS identified might be access to studies, whereas further classification would identify access to prior studies versus access to current studies.

Word clouds are graphical representations of word frequency that give greater prominence to words that appear more frequently in a source text. The larger the word in the visual, the more common the word was in the analysed data. This type of visualization can assist evaluators with exploratory textual analysis by identifying words that frequently appear in a set of interviews, documents, or other texts. It can also be used for communicating the most salient points or themes in the reporting stage. For the word cloud analysis, Orange software version 3.20 was used.

2.5.2. Data management

A de-identified Excel spreadsheet was imported, using STATA software version 15. Different commands assisted in cleaning the data. Checking for duplication, recoding, missing values, and categorising variables were all steps in the data cleaning process. This was a procedure for quality control.

2.5.3 Statistical analysis

In order to compare the different categories, proportions and percentages were used to summarize the categorical variables. The summary of continuous variables was analysed using the mean and the standard deviation, or median with interquartile range. Graphs were also generated. All statistical tests were two sided and p values <0.05 were statistically significant. A p-value <0.10 and >0.05 meant we rejected the null hypothesis and that the variables were the same in all level groups.

2.6. Ethics

Ethical approval to conduct the study was obtained from the Human Research Ethics Committee (Medical) of the University of the Witwatersrand (Approval number: M200606). This certificate is attached as Appendix A.

In order to safeguard the privacy of respondents, all data collected for this study was stored on the researcher's laptop and Google Drive, both of which were password protected. The laptop was always in the custody of the researcher. Other than the researcher, no other person was authorized to access this database. The completed hard copy questionnaires, data collection sheets, and materials from participants were stored in a locked filing cabinet in the researcher's home. No personal identifiers were attached to any data collection tool used in the study.

3. Results

3.1. Classification of level of agreement

In soliciting responses on the perceived benefits and challenges of PACS the questionnaires utilised a four point Likert scale: 1) Strongly Disagree, 2) Moderately Disagree, 3) Moderately Agree, and 4) Strongly Agree. For the purpose of using 2x2 Chi-square tests, these four categories were collapsed such that “Disagree” included “Strongly Disagree” and “Moderately Disagree”, and “Agree” included “Moderately Agree” and “Strongly Agree”

3.2. Classification of percentage of agreement

For the purpose of analysing levels of agreement specific to those questions measuring the perceived benefits and challenges of PACS, the following categories of agreement were used:

Strong Agreement 75% - 100%

Moderate Agreement 50% - 74%

Minimal Agreement 25% - 49%

Little Agreement 0% - 24%

3.3 Survey response summary:

Convenience sampling of the referring clinicians with PACS experience at the academic hospital resulted in the distribution of 682 questionnaires. The clinicians that responded were 372. The calculated response rate was 54.5%.

3.4 Questionnaire reliability

The reliability of the questionnaire was measured using Cronbach's alpha. The values of this measure were above 0.70 for the statements regarding perceived benefits, and they were less than 0.70 for the statements evaluating perceived challenges. Cronbach's alpha should not be less than 0.70. The r-coefficients were below 0.9, showing less correlation in the questions. This is demonstrated in Tables 3.1 and 3.2 below.

Table 3.1: Perceived benefits questions reliability tests.

Variable	Mean	SD	r-coefficient	Alpha
Statement 1	3.57	0.52	0.5798	0.7911
Statement 2	3.53	0.54	0.7133	0.7696
Statement 3	3.4	0.52	07242	0.7677
Statement 4	3.26	0.99	0.4027	0.8161
Statement 5	3.25	0.47	0.7519	0.7628
Statement 6	3.38	0.77	0.4957	0.8035
Statement 7	3.31	0.52	0.6805	0.7750
Statement 8	3.52	0.71	0.5360	0.7976
Statement 9	3.35	0.52	0.7281	0.767

SD; standard deviation

Table 3.2: Perceived challenges statement reliability test.

Variable	Mean	SD	r-coefficient	Alpha
Statement 10	1.84	0.62	0.4264	0.6827
Statement 11	1.85	0.51	0.5375	0.6567
Statement 12	2.28	0.67	0.6169	0.6344
Statement 13	2.86	0.59	0.4845	0.6682
Statement 14	2.08	0.59	0.6224	0.6335
Statement 15	2.31	0.7	0.6551	0.6233
Statement 16	2.23	0.7	0.5913	0.6413
Statement 17	3.32	0.58	0.3841	0.6907
Statement 18	2.79	1.03	0.5019	0.6717

SD, Standard deviation.

3.5. Demographics

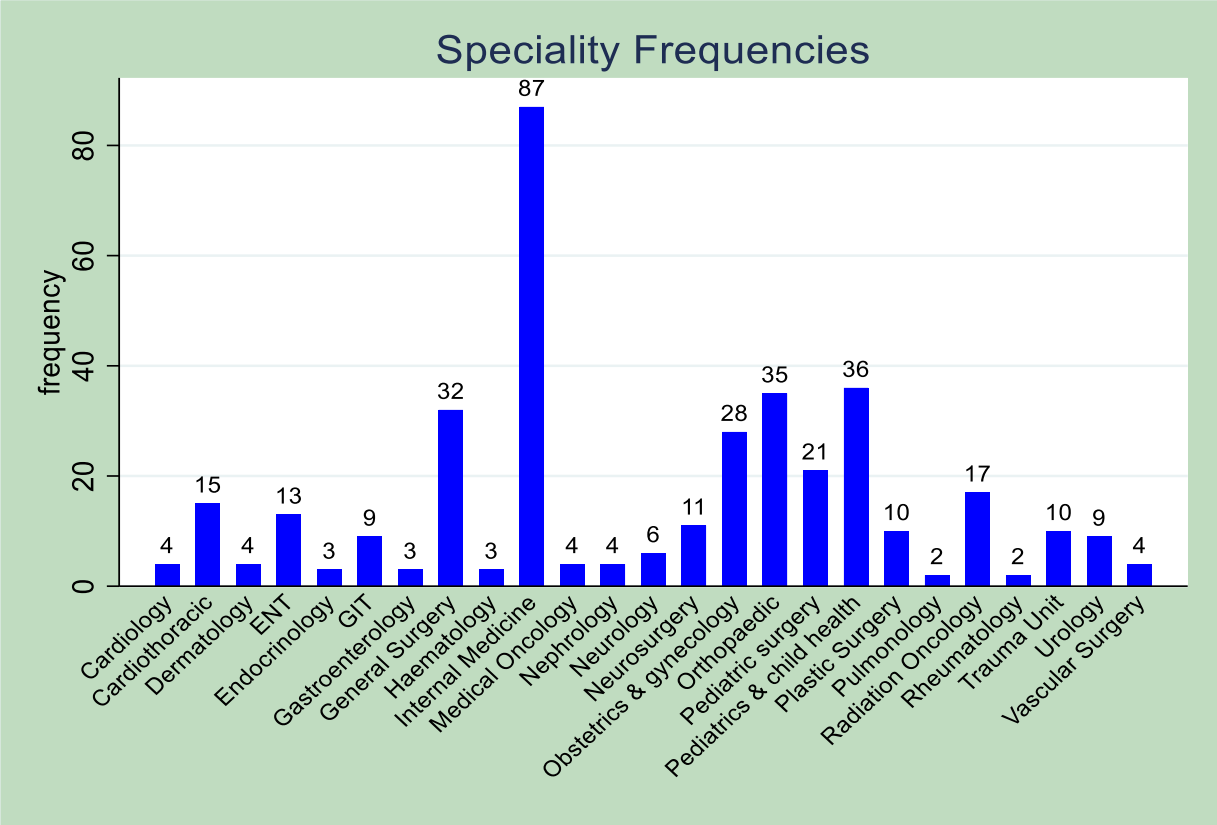


Figure 3.1. Distribution of clinicians by speciality.

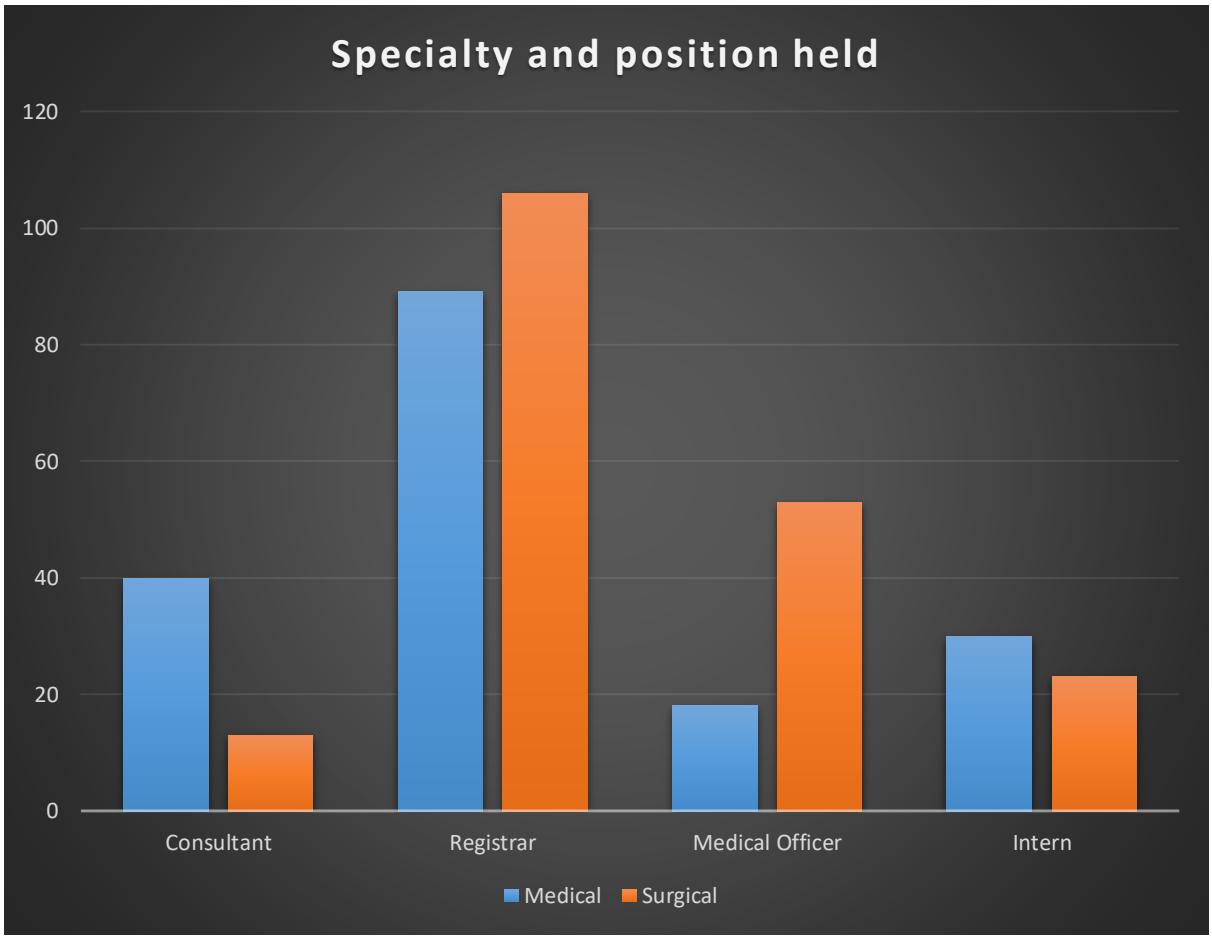
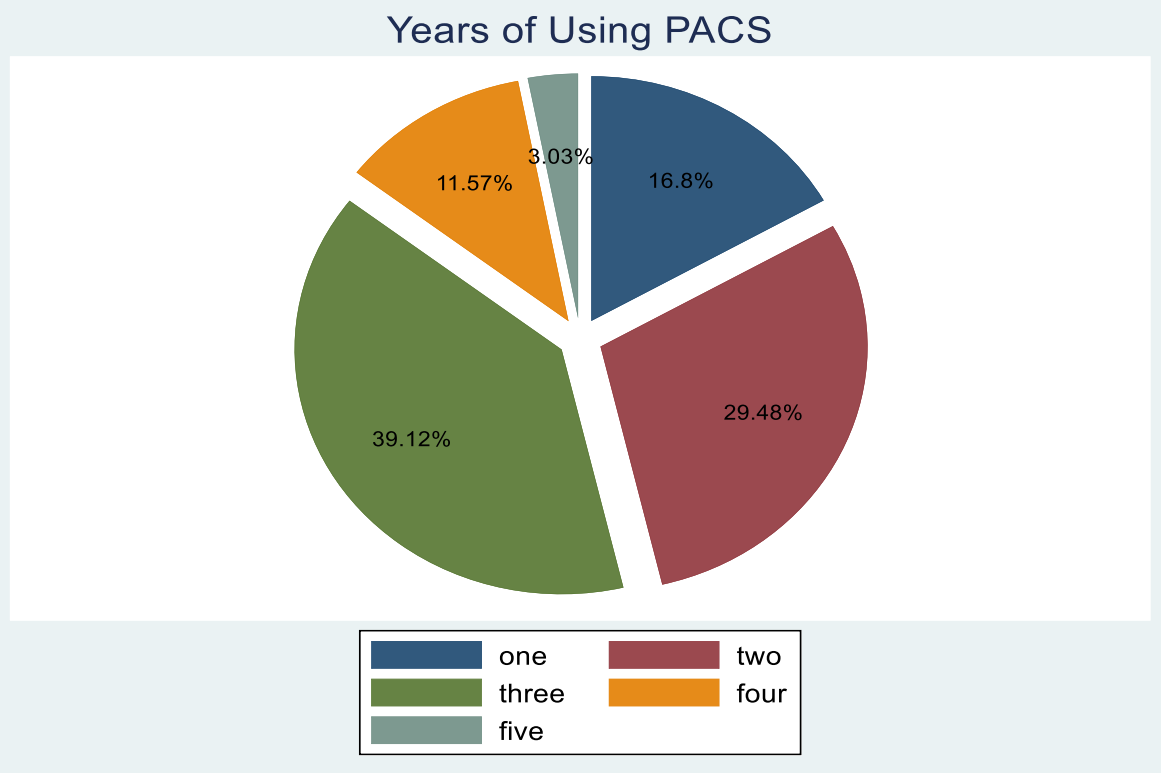


Figure 3.2: Participant's distribution according to position held and specialty

Distribution of participants by area of specialty and position held are presented in Figure 3.1 and 3.2 respectively. The highest number of respondents were registrars 194/372 (52%), followed by medical officers 71/372(19%), interns 54/372(15%) and consultants 53/372(14%).

The distribution of participants by years of PACS experience is presented in Figure 3.3 and 3.4 below. The two frequent PACS years of experience were three years (39.12%) followed by two years (29.48%). Overall, the mean (SD) for using PACS by position held was 2.5(1.03) years. Consultant mean was 3.38(0.93) years and interns had the lowest mean of 1.42(0.75)

years. When categorized to the nearest number, the majority had used PACS for 3 years composing 39% of the respondents, and only 3% had used PACS for 5 years.



PACS; Picture Archiving and Communications Systems

Figure 3.3. Chart of participants' years of PACS experience.

The results showed that majority of respondents accessed PACS for both reports and examinations. 28/54 (51.9%) interns accessed reports only, while 26/54 (48.2%) accessed both reports and examinations. Majority of consultants 52/53 (98%), medical officers 67/69 (97%), and registrars 183/194(94%) accessed both reports and examinations. This was statistically significant with p-value (0.001).

The vast majority of the respondents accessed PACS from a hospital PC workstation 370/372 (99.5 %). The other 0.5% accessed PACS from portable mobile devices.

3.6. Survey Results

Table 3.3: PACS survey results.

		N (%)				
Statement		**Strongly agree**	**Agree**	**Neutral**	**Disagree**	**Strongly disagree**
1	PACS has reduced the time I must wait to review an exam (images).	208 (55.7)	159 (46.6)	3 (0.1)	2 (0.1)	0 (0)
2	I access exams more frequently with PACS than I do with film	192 (51.6)	176 (47.3)	2 (0.1)	0 (0.0)	2 (0.1)
3	PACS has facilitated consultation between myself, other clinicians and/or radiologists	222 (59.7)	145 (39)	3 (0.1)	0 (0.0)	1 (0.1)
4	My efficiency has improved because of PACS	86 (23.1)	157 (42.2)	50 (13.4)	69 (18.5)	10 (2.7)
5	PACS has improved my ability to make decisions regarding patient care	95 (25.5)	274 (73.7)	1 (0.1)	1 (0.1)	1 (0.1)
6	PACS has led to a reduction in my patients' length of stay in hospital	79 (21.2)	228 (61.3)	21 (5.6)	43 (11.6)	1 (0.1)
7	PACS has reduced the number of exams reordered because the exams were not available (lost or located elsewhere) when I needed them	112 (30.1)	249 (67.0)	6 (1.6)	4 (1.1)	0 (0)
8	PACS has enhanced patient care and service delivery at Charlotte Maxeke Johannesburg Academic Hospital	117 (31.5)	210 (56.5)	41 (11.0)	1 (0.1)	2 (0.1)
9	PACS has improved medical student/registrar teaching	116 (31.2)	248 (66.7)	7 (1.9)	1 (0.1)	0 (0)
10	PACS produces inadequate image quality on our image review stations	1 (0.1)	6 (1.6)	6 (1.6)	271 (73)	87 (23.4)
11	I have difficulty finding images/reports when needed	0 (0)	1 (0.1)	4 (1.1)	299 (80.4)	67 (18.0)
12	I experience inadequate workstation performance (Speed).	6 (1.6)	89 (34)	7 (1.9)	252 (67.7)	18 (4.8)
13	I have inadequate access to PACS viewing stations	19(5.1)	275 (74.0)	5 (1.3)	63 (16.9)	8 (2.2)
14	I have difficulty logging on to the system	4 (1.1)	27 (7.3)	7 (1.9)	308 (82.8)	26 (7.0)
15	PACS downtime is higher than acceptable (Malfunction of system)	5 (1.3)	91 (24.5)	10 (2.7)	248 (66.7)	17 (4.6)
16	I have received insufficient training in this new technology	2 (0.1)	68 (18.2)	12 (3.2)	268 (72.0)	21 (5.7)
17	I am unable to view images at the patient's bedside (PC or Mobile devices)	126 (33.9)	230 (61.8)	4 (1.1)	8 (2.1)	4 (1.1)
18	I experience a lack of availability of the system support (From PACS administrators).	9 (2.4)	129 (34.7)	50 (13.4)	176 (47.3)	6 (1.6)

Table 3.4. Perceived benefits of PACS survey results.

Variable	Total	Consultant	Intern	Medical Officer	Registrar	p-value
PACS has reduced the time i must wait to review (images)						
Agree	367(98)	56(96)	54(100)	70(99)	192(99)	
Disagree	2(1)	1(2)	0(0)	1(1)	0(0)	0.272
Neutral	3(1)	1(2)	0(0)	0(0)	2(1)	
I access exams more frequently with PACS than film						
Agree	368(98)	51(96)	54(100)	71(100)	192(99)	
Disagree	2(1)	2(4)	0(0)	0(0)	0(0)	0.114
Neutral	2(1)	0(0)	0(0)	0(0)	2(1)	
PACS has facilitated consultation with other clinicians						
Agree	367(98)	51(96)	54(100)	70(100)	192(99)	
Disagree	1(1)	1(2)	0(0)	0(0)	0(0)	0.311
Neutral	3(1)	1(2)	0(0)	0(0)	2(1)	
My efficiency has improved because of PACS						
Agree	243(65)	15(28)	51(94)	49(69)	128(66)	
Disagree	79(21)	23(44)	1(1)	12(17)	43(22)	<0.001
Neutral	50(14)	15(28)	2(3)	10(14)	23(12)	
PACS improved ability to make patient care decisions						
Agree	369(98)	52(98)	54(100)	70(99)	193(99)	
Disagree	2(1)	1(2)	0(0)	1(1)	0(0)	0.343
Neutral	1(1)	0(0)	0(0)	0(0)	1(1)	
PACS has led to a reduction in my patients' LOS in hospital						
Agree	307(82)	39(74)	54(100)	62(87)	152(78)	
Disagree	22(6)	8(15)	0(0)	1(2)	13(7)	0.604
Neutral	43(12)	6(11)	0(0)	8(11)	29(15)	
PACS has reduced the number of exams reordered.						
Agree	36(97)	52(98)	53(100)	71(100)	185(95)	
Disagree	6(2)	1(2)	0(0)	0(0)	5(1)	0.075
Neutral	4(1)	0(0)	0(0)	0(0)	24(12)	
PACS enhanced patient care and service delivery at CMJAH						
Agree	327(88)	42(81)	53(980	64(90)	168(87)	
Disagree	3(1)	1(2)	0(0)	0(0)	2(1)	0.075
Neutral	41(11)	9(17)	1(2)	7(10)	24(12)	
PACS has improved medical student/registrar teaching						
Agree	364(97)	50(94)	54(100)	71(100)	189(97)	
Disagree	1(1)	1(1)	0(0)	0(0)	1(1)	0.132
Neutral	7(2)	2(3)	0(0)	0	7(2)	

PACS, Picture archiving and Communications Systems; CMJAH, Charlotte Maxeke Johannesburg Academic Hospital; LOS, Length of stay

3.7.1. Perceived benefits:

As presented in Table 3.3, six years post PACS implementation at CMJAH, most clinicians strongly agree that PACS has:

- Reduced the hospital patient length of stay (83%).
- Improved ability for decision making regarding patient care (98%).
- Enhanced patient care and service delivery (88%).
- Shortened review time of an exam (98%).
- Increased access to more exams than with film (99%).
- Improved teaching of medical students and registrars (98%).
- Improved consultation with other clinicians or radiologists (99%).
- Reduced the number of repeat examinations (97%).

There was some moderate agreement that PACS has increased the effectiveness of clinicians (65%).

Of the nine benefit measures asked to clinicians with respect to the position held, there were no notable variations in the degree of agreement with respect to: Time taken to review an exam (p=0.272), radiological examinations being more frequently accessed using PACS than with film (p=0.114), impact of PACS on improved consultation with other clinicians/radiologists (p=0.311), improved ability to make decision making regarding patient care (p=0.343), reduced number of repeat exams (p=0.075), enhanced patient care and service delivery (p=0.075), improved teaching of medical student and registrars (p=0.132), reduced length of patients stay at the hospital (p=0.604).

As presented in Table 3.4 there was significant difference among respondents in the percentage agreement with respect to impact of PACS on improved efficiency (p=0.02).

3.7.2. Perceived challenges

As presented in Table 3.3, the majority of the clinicians had strong agreement that there was inadequate access to PACS workstations (80%) and inability to view images at the bedside using portable devices (96%). There was minimal agreement that there was inadequate workstation performance speed (25%), higher than acceptable downtime (26%), and lack of system support availability (37%). There was little agreement that the use of PACS had resulted in poor image quality (2%), that they had received inadequate PACS training (19%), that they had difficulty finding the exams they needed on PACS (1%), or that they had trouble logging into the PACS (8%).

Only three of the nine variables used to measure perceived drawbacks, as shown in Table 3.5, were thought to differ significantly among clinicians with respect to position held. Of the interns, 50% agreed they received insufficient training, while only 19% of registrars, 7% of consultants, and 4% of medical officers felt this was the case (p=0.001). Lack of availability of system support was identified by 50% of the interns, 44% of registrars, 22% of consultants, and 21% of medical officers (p=0.001). Downtime being higher than acceptable was identified by 26% of consultants, 30% of medical officers, 29% of registrars, and 9% of interns (p=0.001).

The overall distribution of respondents for each benefit and challenge statement is represented in pie charts (Appendix D).

Table 3.5. Perceived challenges survey results:

N(%)

Variable	Total	Consultant	Intern	M.O	Registrar	p-value
Inadequate image quality						
Agree	7(2)	4(7)	0(0)	0(0)	3(2)	
Disagree	358(96)	47(89)	53(98)	69(98)	189(97)	0.050
Neutral	6(2)	2(4)	1(2)	1(2)	2(1)	
Difficulty finding images						
Agree	1(1)	0(0)	0(0)	1(2)	0(0)	
Disagree	366(98)	52(98)	53(98)	70(98)	191(99)	0.434
Neutral	4(1)	1(2)	1(2)	0(0)	2(1)	
Inadequate workstation performance						
Agree	95(25)	11(21)	7(13)	23(32)	54(28)	
Disagree	270(73)	40(75)	47(87)	47(66)	136(70)	0.096
Neutral	7(2)	2(4)	0(0)	1(2)	4(2)	
Inadequate access to workstation						
Agree	294(80)	36(68)	41(77)	61(86)	156(81)	
Disagree	71(19)	17(32)	12(23)	10(14)	32(17)	0.088
Neutral	5(1)	0(0)	0(0)	0(0)	5(2)	
Difficulty logging in						
Agree	31(8)	4(8)	7(13)	2(3)	18(9)	
Disagree	334(90)	47(88)	47(87)	68(96)	172(89)	0.289
Neutral	7(2)	2(4)	0(0)	1(1)	4(2)	
Downtime higher than acceptable						
Agree	96(26)	14(26)	5(9)	21(30)	56(29)	
Disagree	265(71)	36(68)	49(91)	47(70)	131(67)	0.007
Neutral	10(3)	3(6)	0(0)	0(0)	7(4)	
Insufficient PACS training						
Agree	70(19)	4(7)	27(50)	3(4)	36(19)	
Disagree	289(78)	47(87)	26(48)	67(94)	150(78)	<0.001
Neutral	12(3)	3(6)	1(2)	1(2)	7(3)	
Cannot view images at bedside						
Agree	356(96)	51(96)	52(98)	70(99)	183(94)	
Disagree	11(3)	2(4)	1(2)	1(1)	7(4)	0.840
Neutral	4(1)	0(0)	0(0)	0(0)	4(2)	
Lack of availability of system support						
Agree	138(37)	12(22)	27(50)	15(21)	84(44)	
Disagree	182(49)	30(57)	22(41)	46(65)	84(44)	0.001
Neutral	50(14)	11(21)	5(9)	10(14)	24(12)	

M.O, Medical Officer

3.8. Open ended questions:

3.8.1. Benefits and challenges:

A total of 66/371 (17.8%) clinicians responded to the open ended question on additional comments on benefits and challenges. The total number of views expressed were 93. Positive comments were 46, negative comments were 41, and non-relevant were 6. Of the total number of views expressed (N = 93), 48% were focused on benefits, whereas 46% mentioned challenges.

Table 3.6: Summary of open ended question comments.

Open ended responses (Total comments = 93)			
Benefits	**N (%)**	**Challenges**	**N (%)**
Overall positive responses included words and phrases like: 'Saves time', ' hugely beneficial', 'great', 'splendid', 'perfect', 'good', 'better', 'no more lost films', 'timely access', 'efficient', 'amazing', 'way to go', 'easy image comparison', 'all images in one file', 'makes life easy', 'easily accessible', and 'works well'	46 (49.4%)	Few PACS access workstations	16 (17.2%)
		Lack of advanced image viewing manipulating tools	9 (9.7%)
		Power outage related downtime	8 (8.6%)
		Lack of beside or offsite access to PACS.	5 (5.4%)
		Other	3 (3.1%)
		Neutral comments	6 (6.6%)
Total comments= 46 (49.4%)		**Total comments = 47 (51.6%)**	

A summary of the remarks made by respondents made respondents is shown in Table 3.6. Taking into consideration that some respondents passed more than one comment in their response, the researcher determined if the views expressed were either negative or positive, and documented them as either a benefit or a challenge. A summary of positive comments is presented in a word cloud graph in figure 3.4.



PACS; Picture Archiving and Communication Systems.

Figure 3.4: Word cloud graph of positive comments.

PACS access was identified by 17.2% of the respondents as a significant challenge, whether in a clinic environment or in wards. This was followed by lack of advanced image viewing software 9.7%, power outage related downtime 8.6%, and lack of bedside access to PACS 5.4%. The distribution of negative comments is presented in Figure 3.5.

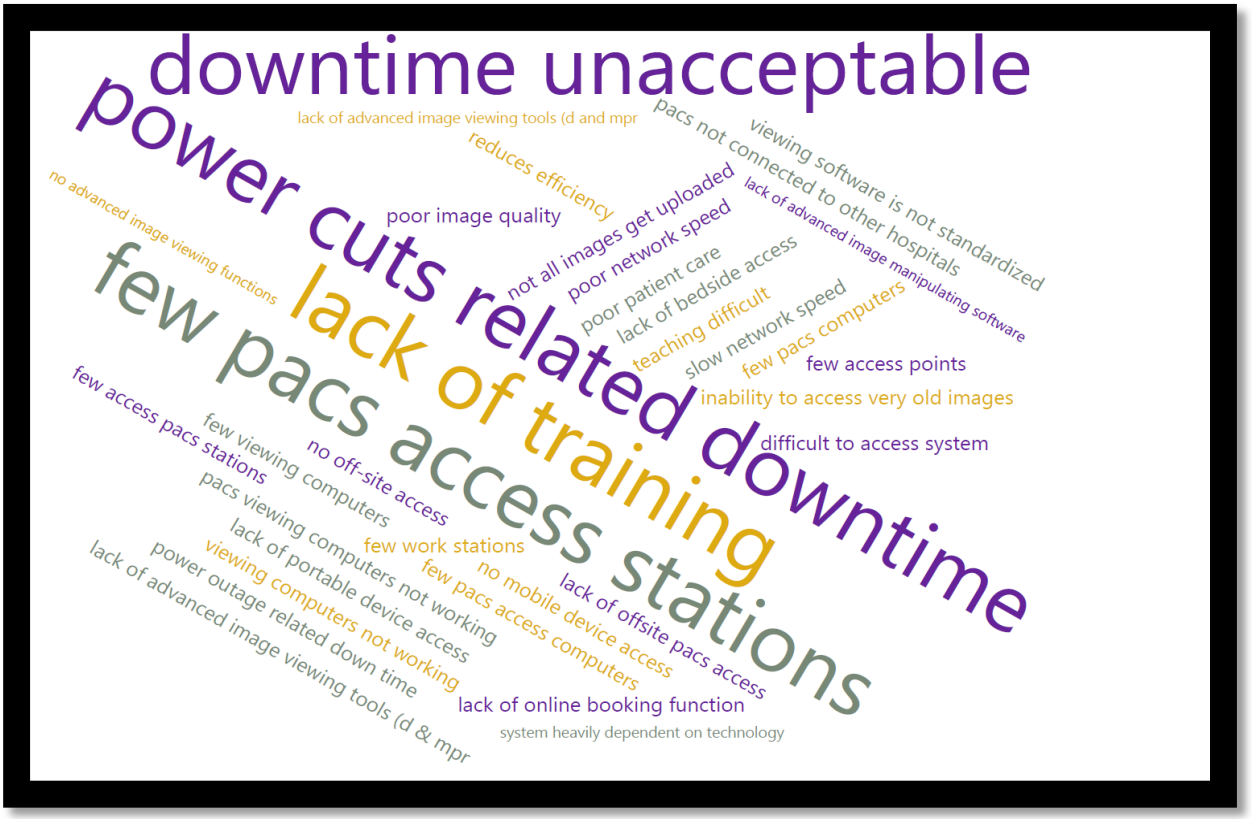


Figure 3.5: Word cloud graph of negative comments.

3.8.2. Recommended improvements:

Table 3.7 provides an overview of the suggestions offered by the respondents on how to improve the current system. A total number of 230/372 (61%) responses were received from respondents. After subjective categorization, the total number of views identified as recommended improvements were 466. The most frequent recommendations were: Increase PACS access in wards, clinics and bedside with 157/466(37%), enable PACS access via portable devices with 143/466(31%), install advanced image viewing software 36/466 (8%), introduce online booking system integrated with PACS (7%), integrate system with other hospital PACS or setup a provincial PACS system (5%), increase the number of PACS training workshops and technical support (5%), and offsite access to PACS (4%).

Table 3.7: Proposed recommendations for PACS improvement.

(N=466)

PROPOSED IMPROVEMENTS	N	Percent
Increase PACS access workstations in wards/clinics/bedside	157	34%
Enable PACS access via Portable devices	143	31%
Install advanced image viewing software MPR, MIP, 3D, virtual bronchoscopy	36	8%
Introduce online booking system	34	7%
Integrate system with other hospital PACS (Provincial PACS)	24	5.2%
More PACS training workshops and technical support	22	5%
Offsite access to PACS	20	4%
Improve network speed	10	2%
Integrate PACS with EMR	5	1%
Decrease downtime	5	1%
Improve image quality	1	0.2%
Connect PACS to a UPS	3	0.6%
Archive ECHO, ECG, cardiac catheterisation, and arthroscopy on to PACS	2	0.4%
Improve security, offer all users unique login	1	0.2%
Other comments: Unknown, nothing, Is there mobile device access?	3	0.6%

MPR, Multiplanar Reformation; MIP, Maximum Intensity Projection; PACS, Picture Archiving and Communication Systems; EMR, Electronic Medical Record; UPS, Uninterrupted Power Supply; ECH0, Echocardiogram; ECG, Electrocardiogram.

4. Discussion

PACS has changed the practice of radiology and medicine in the past four decades. There are significant benefits to bringing PACS to the clinical setting, both in outpatient departments and in wards. Although most clinicians considered PACS advantageous, a significant number encountered issues concerning accessibility and functionality of the system. The key changes suggested also focused on PACS accessibility and functionality.

4.1. Perceived benefits of PACS

The following advantages of PACS in the highlighted categories are the main topic of discussion:

- Time to review exams and ease of access to exams.
- Patient care and service delivery.
- Consultation with other clinicians.
- Efficiency and Academic teaching.

4.1.1. Time to review exams and ease of access to exams

Over 95% of clinicians concurred that PACS had reduced the time to review exams and that they accessed exams most frequently with PACS than with film. Access to prior exams helps clinicians evaluate disease progression and the extent of treatment response. The ability to quickly scroll through images expedites the time taken to go through an exam compared to loading films on a film box in their correct order and then reading through them.

The literature for the most part, remained silent on the issue of whether quick access to images has any impact on better clinical outcomes.

4.1.2. Patient Care and service delivery:

The strong agreement response on improved patient care and service delivery compares with the high level of agreement observed in other studies. Lenhart (14) conducted a study on 'PACS: Acceptance by orthopaedic surgeons' wherein she recorded 64% agreement that PACS improved patient care. There are no specific studies in the literature that specifically focus on the impact of PACS on improving patient care. It is difficult to come up with an objective measure for patient care. Watkins (8) concluded that there was no clearly discernible influence of PACS on clinical decision making; however, prompt access to images could have some beneficial impact. This is particularly the case in the ICU and the emergency department, where immediate access to images is thought to be more critical in influencing further patient management.

4.1.3. Reduced hospital length of stay:

It can be hypothesised that prompt access to radiology reports and exams via PACS may result in prompt decision making and initiation of treatment, thereby reducing the patient's length of stay. In a study conducted in Saudi Arabia evaluating PACS at three ministry hospitals (King Salman, Alyamama, and Imam Abdulrahman Alfaisal Hospitals) by Alalawi et al. (28), 79% of the participants agreed with this statement. However, in another study evaluating the benefits of PACS, Bryan et al. (7) concluded that there was no convincing evidence that PACS reduced the length of an inpatient stay. This was further supported by a study conducted by MacDonald et al. (13) that concluded that the length of stay was not significantly impacted by PACS. They pointed out many external influencing factors to PACS such as clinician practice, hospital type and policy, and patient comorbidities. Although our local clinicians communicated a reduced hospital stay with PACS, examples of some external factors include the following: Charlotte Maxeke Johannesburg Academic Hospital is

overburdened by many emergency cases, resulting in a lack of availability of high care or ICU beds, which further delays the scheduling of some major elective cases that require post-operative admission to these units. Some of the equipment required for surgical procedures is outsourced to private companies, e.g., the equipment for neuro-monitoring and neuro-navigation; however, if these companies are fully booked, there may be a delay in the scheduling of neurosurgical procedures, increasing the hospital length of stay.

4.1.4. Consultation with other clinicians and impact on efficiency

The authors expected PACS to reduce the interaction between clinicians and radiologists due to the availability of images and reports at multiple sites within the hospital. This study's results strongly supported this argument: 98% of clinicians agreed that PACS had facilitated consultation among clinicians, and clinicians with radiologists. A limitation of the study is that consultations among clinicians themselves, and consultations between clinicians and radiologists were not separated. This question should have been split into two to specify the type of consultation. MacDonald et al. (13) documented reduced in-site consultations with radiologists, and increased offsite consultations between radiology and clinicians in a provincial PACS-based system study. There was moderate agreement of (66.4%) that PACS had increased offsite consultations. Redfern et al. (29) supported the notion that the availability of PACS stations in clinical areas would lead to decreased consultations with radiology. Most clinicians suggested they saved time by no longer consulting with the radiology department to view images or reports. The radiology exams were readily available at multiple clinician workstations immediately after the images were acquired. Treatment planning could commence prior to the patient's return from the radiology department. This

benefit was particularly observed in the emergency medicine and trauma units. Impact on Academic Teaching Regarding the impact of PACS on the teaching of me.

4.1.5. Impact on academic teaching:

Regarding the impact of PACS on the teaching of medical students and registrars, there was a moderate agreement of 67% that there was an improvement. These results correlate with the study by Jorwekar et al. (1) where 51% of the respondents were in agreement. Picture archiving and communication systems is valuable for teaching due to the ease with which images can be compared, the convenience with which exams can be archived for use in teaching, and the ease with which image quality may be manipulated.

4.2. Perceived challenges

The discussion that follows focuses on the PACS drawbacks listed below:

- PACS access
- Image quality and speed,
- System support and training.

4.2.1. PACS access

The challenges most often cited were the inability to view the images at the bedside, the lack of portable device access, and the few available viewing stations. While this limitation could be a gap in the implementation plan, it must be analysed within the context of what is practical in the hospital setting of interest. It would be costly to set up workstations at every bedside-in a public sector hospital in a low- to middle-income country; logistically near

impossible. Theft of equipment was highlighted as a challenge by the PACS administrators. One practical solution would be for clinicians to access PACS from their portable devices (tablets, laptops, and mobile phones). This would reduce the capital cost of deploying more workstations.

4.2.2. Image quality & performance (speed)

Although image quality assessment is subjective and dependent on the viewing platform, the majority of the respondents were satisfied with the image quality. Only 2% of respondents stated that PACS produced inadequate image quality. Although entry level clinician workstation monitors are not held to the strict quality control standards of dedicated diagnostic display units used for formal radiology reporting, recent technological advances yield these monitors sufficient for general hospital-wide image review. Mobile device technology has certainly matured significantly for use by radiologists in the on-call, hospital offsite setting and by doctors at the bedside or in the operating theatre (26). Slow image retrieval can be attributed to network speed, which is more of an IT support issue, although no formal assessment of this factor was done. Furthermore, the recent electricity supply challenges faced by the country affected the network connectivity and speed.

4.2.3. System support and training:

Insufficient PACS training was reported by 24% of responding clinicians, and 36% agreed that they experienced a lack of system support from PACS administrators. Although 20% – 40% of the respondents did not constitute a majority, this nonetheless suggests there are training and support issues to be addressed. Picture archiving and communication systems administrators conduct two training workshops every year, however, the turnout of

clinicians during these PACS training workshops is usually low. This could in part explain why some clinicians felt that they did not receive adequate training. A limitation of the study is the fact that the roles of IT support and PACS administrators were not distinguished when it came to system support.

4.3. Improvements

The most frequent recommendations 320/466 (68%) were related to PACS access. Very few clinicians were aware that PACS can be accessed via portable devices (personal tablets, laptops, and cell phones) from within the hospital. The hospital PACS is wired through a local area network (LAN) and is web-based. The hospital already has the infrastructure to facilitate wireless connectivity to this network. Devices to be connected to this network will need to be configured by the IT department. Some doctors opined that they were able to access laboratory results from their portable devices through internet connection; hence, the same technology could be availed for PACS access. One respondent commented that the network is very slow on portable devices. Offsite access will be beneficial to clinicians who are on call as they will be able to view images in the comfort of their homes or call rooms. Furthermore, this will benefit those who would want to access images for teaching purposes on virtual platforms. This will require an upgrade to a private cloud-based PACS which is more cost-effective, reliable and secure (27). Off-site access to PACS is a challenge for onsite PACS systems due to security and privacy requirements; therefore, onsite PACS solutions have trouble transmitting secure data outside of their immediate area (30). Contrarily, cloud PACS designed for offsite access and providers follow stringent security and privacy guidelines (30). Budget constraints, funding, current PACS vendor's contractual obligations

and government decisions may influence the hospitals' decisions on which PACS system to upgrade to. Few comments recommended the deployment of a provincial PACS 24/466 (5%). This will significantly reduce the number of repeat exams, as well as the number of unnecessary patient transfers as a result of prior image review and consultations. The referring hospitals connected to CMJAH PACS include Berta Gxowa, Far East Rand, Sizwe, and Pholosong hospitals. At the time of this writing, efforts were being made to connect Leratong, Helen Joseph and Yusuf Dadoo hospitals. The downside of this connectivity is that it is one way, with only CMJAH being able to access studies done from the connected hospitals. Clinicians from referring hospitals are unable to access the CMJAH PACS. The iSite archive could not be integrated into the other hospital archives as they use different running software. These have different repository archives, architectures and data registry. Charlotte Maxeke Johannesburg Academic Hospital has computers installed with software compatible with the referring hospitals, allowing it to access studies done at these hospitals. Most clinician PACS workstations are equipped with basic image manipulating tools, which include zoom, panning, measure, window and level function. Some clinicians highlighted the need to have more advanced hanging protocols and image manipulation tools similar to those found in the radiology PACS workstations. These include 3-D reconstruction, Multiplanar Reformation (MPR), virtual bronchoscopy, virtual colonoscopy and angiography post processing techniques for planning endovascular aneurysm repair. It is impractical to equip every clinician PACS station with advanced image viewing software due to the cost involved. The solution would be to customise the image viewing software according to speciality requirements. Only 7% of comments referred to an online booking system for radiology exams. This recommendation came mainly from interns, medical officers and registrars. Most of these respondents suggested this will increase their efficiency as they will spend less time going to the radiology department. From a radiology department perspective, physical

bookings have the advantage of planning a patient's imaging in consultation with the requesting clinician, which will aid coming up with the best modality suitable for the clinical question and ultimately reduce unnecessary bookings. Telephonic discussions and online booking systems are compelling options to consider in the post-coronavirus disease 2019 (COVID-19) milieu, where everything has moved to digital platforms and remote access. In this study, issues raised regarding downtime were specifically related to power cuts rather than routine scheduled maintenance. At the time of writing, South Africa was experiencing severe power outages; this crisis is predicted to continue into the near future. Connecting the entire PACS infrastructure to an uninterrupted power supply (UPS) system was suggested as an option to mitigate downtime. The radiology department prints hard copy films for clinicians during PACS downtime. Uninterrupted power supply (UPS) connectivity will help minimise film printing costs.

4.4. Limitations of the current study

1. The study was limited to a post -PACS implementation evaluation. To significantly access the impact of PACS on clinical practice, a study which involved the pre- and post-implementation would have been ideal. However, this was not feasible as there were few respondents from the pre-implementation era.

2. Despite a reasonable sample size, the response rate was low at 54%. At the time of writing, the hospital was only partially open due to ongoing renovations after a fire incident which forced the entire hospital to close in 2021. Some departments were still not fully functional with their staff deployed to satellite hospitals. This could have contributed to the low response rate.

3. Only clinicians referring patients to the radiology department were included. The study excluded radiologists. Hence, there is a need for further research to validate research findings by comparing outcomes of PACS users working in different environments.

4. During data analysis, detailed information could have been lost by collapsing the four-point Likert scale to two categories, which were ‘disagree’ and ‘agree’.

4.5. Implications of findings and future applications

Major hospitals in Gauteng province are expanding their PACS to a hospital wide PACS system incorporating the emergency departments, wards, clinics, and the outpatient departments. There are plans of setting up a large PACS systems spanning several hospitals within the province. It is clear that physician input will be necessary for future PACS implementation projects, and specific department requirements for the end-user viewing software hanging tools should be taken into consideration. It is projected that the current infrastructure will need to be upgraded, especially through additions like off-site access to PACS, the introduction of online exam booking, and mitigation of power-cuts related downtime.

It is apparent from this study that most clinicians were unaware that PACS can be accessed from portable devices through the hospital LAN. The IT department in collaboration with the PACS administrators need to educate the clinicians about mobile device connectivity. This is particularly of importance as shortage of PACS access workstations was mentioned as one of the major drawbacks.

In public hospitals, additional research is required to compare the feasibility and cost-effectiveness of a cloud-based PACS system to the onsite PACS system now in use with a local archive.

5. Conclusion

The results of this study provides overwhelming that medical practitioners are in favour of implementing a hospital wide PACS. The benefits of PACS, in particular reduction of repeat imaging, ease of comparison with previous imaging, images and reports availability at multiple sites at any time, and eliminating the scenario of lost films were seen as compelling rationale for the implementation of a hospital-wide PACS system.

The main challenges raised regarded PACS access both at inpatient and outpatient environments, downtime and the lack of advanced image manipulating tools at clinician workstations. These issues were cited as major areas that need improvements for clinicians to fully realise the benefits of PACS. The case for switching to a cloud-based PACS system is strong given the acknowledged desire from clinicians for offsite access and the difficulties faced by CMJAH with regard to equipment theft, few PACS access stations and frequent power outages.

This study will serve as a benchmark for future hospital and provincial-wide PACS deployment projects in public hospitals.

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Appendix A: Ethics Clearance Certificate

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

R49 Dr P Tshalibe

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
CLEARANCE CERTIFICATE NO. M200606

NAME: **(Principal Investigator)**	Dr P Tshalibe
DEPARTMENT:	School of Clinical Medicine Department of Radiation Sciences Division of Diagnostic Radiology Medical School University
PROJECT TITLE:	*Clinician's perspective of picture archiving and communication systems at Charlotte Maxeke Johannesburg Academic Hospital*
DATE CONSIDERED:	2020/06/26
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Drs J Adrigwe and S Lucas
APPROVED BY:	CB Penny Dr CB Penny, Chairperson, HREC (Medical)
DATE OF APPROVAL:	2021/02/12

This Clearance Certificate is valid for 5 years from the date of approval. An extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office secretariat on the 3rd floor, Phillip Tobias Building, Parktown, University of the Witwatersrand, Johannesburg.

I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated from the research protocol as approved, I/we undertake to submit details to the Committee. **I agree to submit a yearly progress report**. When a funder requires annual re-certification, the application date will be one year after the date when the study was initially reviewed. In this case, the study was initially reviewed in **«Missing mail merge field»** and therefore reports and re-certification will be due in the month of **«Missing mail merge field»** each year. Unreported changes to the study may invalidate the clearance given by the HREC (Medical).

Appendix B: PACS opinion survey questionnaire.

PACS OPINION SURVEY: CLINICIANS

Thank you for agreeing to complete this questionnaire. The purpose of this study is to determine the benefits of Picture Archiving and Communications Systems at Charlotte Maxeke Johannesburg Academic Hospital. This survey looks at your current environment (Sections I), your perceived benefits and potential challenges to using PACS (Sections II and III). Your responses are anonymous; no personal identifiers are attached to this questionnaire

Section I: PACS environment

1) Please indicate your speciality

Internal Medicine	☐	GIT surgery	☐	Endocrinology	☐		
Cardiology	☐	Orthopaedic surgery	☐	Gastroenterology	☐		
Obstetrics/gynecology	☐	Cardiothoracic surgery	☐	Rheumatology	☐		
Radiation Oncology	☐	ENT	☐	Pulmonology	☐		
Pediatrics	☐	Urology	☐	Haematology	☐		
Pediatric surgery	☐	General surgery	☐	Infectious diseases	☐		
Trauma	☐	Neurosurgery	☐	Neurology	☐		
Nephrology	☐	Ophthalmology	☐	Psychiatry	☐		
Emergency Medicine	☐	Plastic surgery	☐	Other, specify_____			

2) Position held at the hospital

Intern	☐	Registrar	☐
Medical Officer	☐	Consultant	☐

3) How many years/months of PACS experience have you had at CMJAH?_____

4) What do you access most frequently?

- ☐ Exams
- ☐ Reports
- ☐ Both

5) Where do you access the PACS system (Tick all that apply)

☐ Hospital PC workstation ☐ Laptop ☐ Mobile device (Pad/Phone)

Section II: Perceived benefits of PACS

In your own opinion what are the benefits in having PACS? Please indicate the extent to which you are agree or disagree with the following statements.

Please respond to statement 6 through 14 by circling on of the following responses:

1	Strongly Disagree (**D**)
2	Moderately Disagree
3	Moderately Agree
4	Strongly Agree (**A**)
5	**Not Applicable (N/A)**

		(D)			(A)	N/A
6)	PACS has reduced the time I must wait to review an exam (Images).	1	2	3	4	5
7)	I access exams more frequently with PACS than I do with film.	1	2	3	4	5
8)	PACS has facilitated consultation between myself, other clinicians and/or radiologists.	1	2	3	4	5
9)	My efficiency has improved because of PACS.	1	2	3	4	5
10)	PACS has improved my ability to make decisions regarding patient care.	1	2	3	4	5
11)	PACS has led to a reduction in my patients' length of stay in hospital.	1	2	3	4	5
12)	PACS has reduced the number of exams reordered because the exams were not available (lost or located elsewhere) when I needed them.	1	2	3	4	5
13)	PACS has enhanced patient care and service delivery at Charlotte Maxeke Johannesburg Academic Hospital.	1	2	3	4	5
14)	PACS has improved medical student/registrar teaching.	1	2	3	4	5

Section III: Potential Challenges of PACS

In your opinion, what are the challenges to using PACS? Please indicate the extent to which you agree or disagree with the following statements.

Please respond to statement 15 through 23 by circling on of the following responses:

1	Strongly Disagree (**D**)
2	Moderately Disagree
3	Moderately Agree
4	Strongly Agree (**A**)
5	**Not Applicable (N/A)**

		(D)			(A)	N/A
15)	PACS produces inadequate image quality on our image review stations.	1	2	3	4	5
16)	I have difficulty finding images/reports when needed.	1	2	3	4	5
17)	I experience inadequate workstation performance (Speed).	1	2	3	4	5
18)	I have inadequate access to PACS viewing stations.	1	2	3	4	5
19)	I have difficulty logging on to the system.	1	2	3	4	5
20)	PACS downtime is higher than acceptable (Malfunction of system).	1	2	3	4	5
21)	I have received insufficient training in this new technology.	1	2	3	4	5
22)	I am unable to view images at the patient's bedside (PC or Mobile devices).	1	2	3	4	5
23)	I experience a lack of availability of the system support (From PACS administrators).	1	2	3	4	5

24) Comments

a) Please use the following space provided below for additional comments on benefits and challenges of PACS.

b) What improvements can be made on current PACS system?

Thank you for taking the time to complete this questionnaire.

Appendix C: Participant information form

INFORMATION FORM

Study Title: ***Clinicians' perspective of PACS at Charlotte Maxeke Johannesburg Academic Hospital.***

Principal Investigator: Dr Polite Tshalibe

Introduction

Good day! I am Dr Polite Tshalibe, from the Division of Diagnostic Radiology in Charlotte Maxeke Johannesburg Academic Hospital. I am conducting a research project, titled above, as part of my MMed studies.

You are invited to take part in my research study. Before you decide whether to participate or not, you need to understand what the study is for, what risks you might be exposed to, and what benefits you might receive. This consent form explains the study.

The researcher will:

- Answer your questions.
- Keep confidential any information which could identify you personally.
- Be available during the study to deal with any problems and answer questions.

You may decide not to take part in, or leave the study, at any time.

Study objective

This study is designed to evaluate the clinicians' satisfaction with the Picture Archiving and Communication systems (PACS). In addition, I hope that it will determine recommendations from clinicians on how the current system might be improved.

Description of the Study Procedures

I plan to distribute a four page questionnaire at departmental meetings to all willing participants. I will arrange for a box to be made available at the departmental secretary's office to deposit completed questionnaires and I will return to collect them a few days later.

This questionnaire will take approximately 15-20 minutes to complete and will contain no personal identifiers. There is no consent form – completing the questionnaire implies consent.

Possible Risks and Discomforts

There are no anticipated risks and discomforts associated with this study. However, participants will be asked to give freely of their time and will be asked to provide frank feedback.

Benefits

It is not known whether this study will benefit you directly. This will depend on the outcomes and management response.

Confidentiality

As mentioned above, there are no identifiers on the questionnaire, so your name will not appear in any report or article published as a result of this study.

Study results

I will be happy to make a summary of the study results available to any interested participant.

Further information

If you have any questions regarding the study, please feel free to contact me or my supervisor. The details are below.

Dr. P. Tshalibe (PI) Tel Number 071 757 2368 and E-mail: politetshalibe@gmail.com
Dr J. Adrigwe (Supervisor) Tel Number 072 408 2212 and E mail: jadrigwe@yahoo.com

This study has been approved by the Human Research Ethics Committee (Medical) of the University of the Witwatersrand, Johannesburg ("Committee"). A principal function of this Committee is to safeguard the rights and dignity of all human subjects who agree to participate in a research project and the integrity of the research.

If you have any concern over the way the study is being conducted, please contact the Chairperson of this Committee who is Dr Clement Penny, who may be contacted on telephone number 011 717 2301, or by e-mail on Clement.Penny@wits.ac.za. The telephone numbers for the Committee secretariat are 011 717 2700/1234 and the e-mail addresses are Zanele.Ndlovu@wits.ac.za and Rhulani.Mukansi@wits.ac.za

Thank you for reading this Study Information Sheet.

November 2020

Appendix D: Consent form

WITS UNIVERSITY

PARTICIPANT CONSENT SHEET

Project Title: Clinicians' perspective of PACS at Charlotte Maxeke Johannesburg Academic Hospital.

1. I have been given a Participant Information Sheet which explains the nature and processes involved in this study, which is attached hereto;
2. I was given time to read it, or had it read to me, in the language I best understand;
3. I was given time to ask any questions I wanted to and found any answers given to me to be reasonable and satisfactory;
4. I believe I fully understand why the study is being conducted and what the intended outcomes will be;
5. I understand that there will be no immediate benefit to me, should I agree to participate, nor will I receive any payment; conversely, participation will not cost me anything but my time;
6. I understand that, even if I initially consent to take part in the study, I may subsequently withdraw at any time and would not be required to give any reasons; if that happened, any data collected about me for the purposes of the study would immediately be destroyed, unless I give consent for it to be retained
7. I have been given a range of contact details, listed below. If I require further information or become concerned about any aspect of this study I am free to speak to any of these contacts.

Contact details:

Principal Investigator: Dr P.Tshalibe telephone no. 0717572368, or by e-mail at politetshalibe@gmail.com,

Supervisor: Dr J. Adrigwe, on telephone no. 072 408 2212 and by e- mail at jadrigwe@yahoo.com

Professor CB Penny, Chairperson of the Human Research Ethics Committee (Medical) at the University of Witwatersrand, on telephone no. 011 717 2301, or by e-mail at Clement.Penny@wits.ac.za.
Ms. Z Ndlovu or Mr Rhulani Mkansi, Committee Secretariat, telephone nos.: 011 717 2700/1234 or by e-mail at: Zanele.Ndlovu@wits.ac.za or Rhulani.Mkansi@wits.ac.za

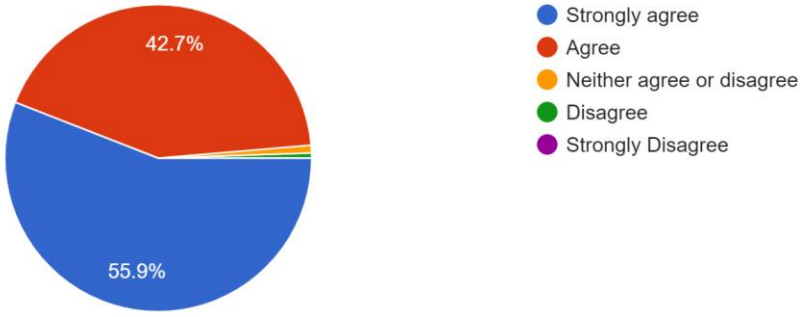
Participant's name and signature: _____

Date: _____

Appendix E: Benefits and challenges statements response distribution

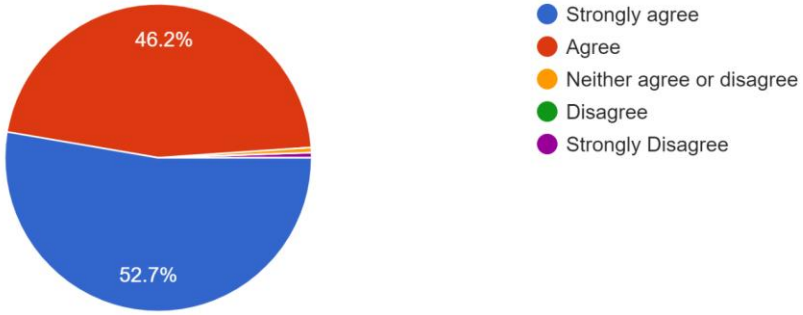
6) PACS has reduced the time i must wait to review an exam (images).

372 responses



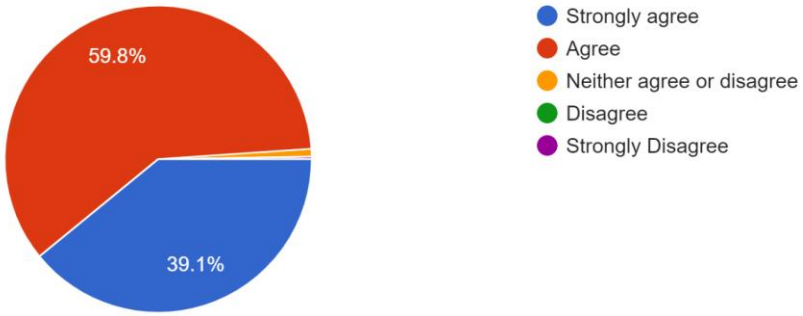
7) I access exams more frequently with PACS than I do with film.

372 responses



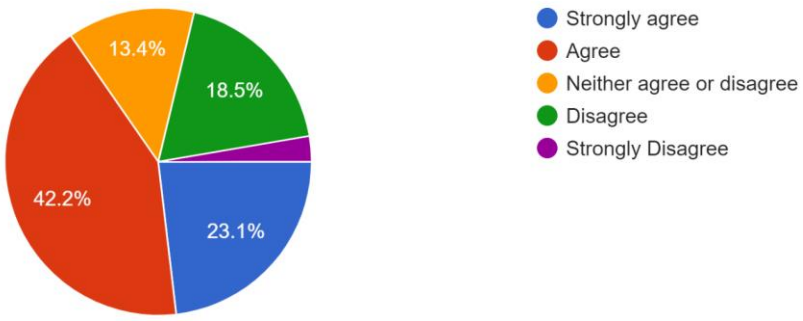
8) PACS has facilitated consultation between myself, other clinicians and/or radiologists.

371 responses



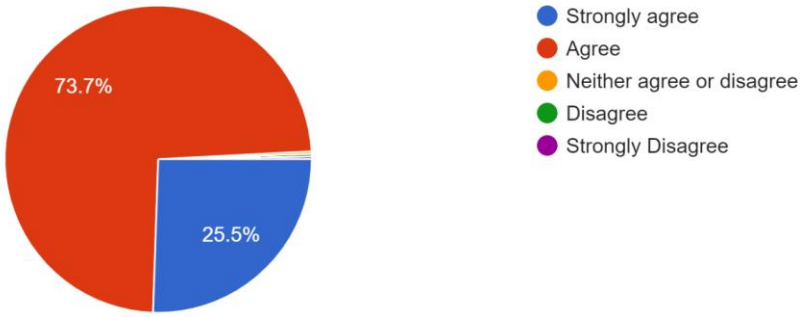
9) My efficiency has improved because of PACS.

372 responses



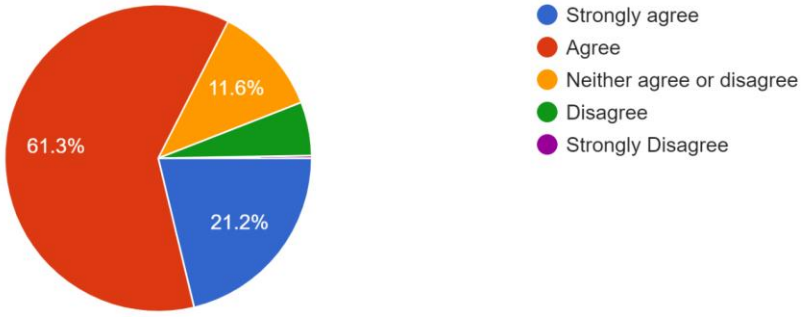
10) PACS has improved my ability to make decisions regarding patient care.

372 responses



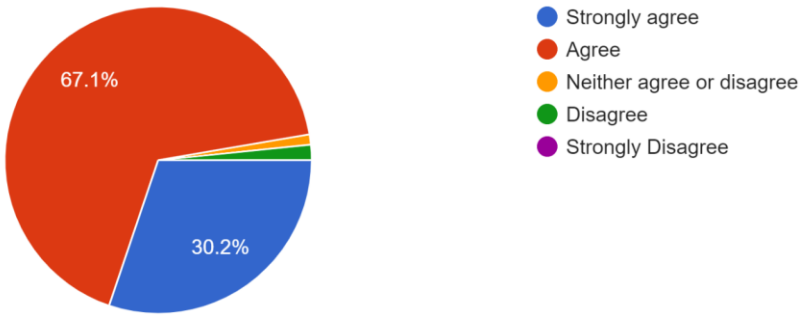
11) PACS has led to a reduction in my patients' length of stay in hospital.

372 responses



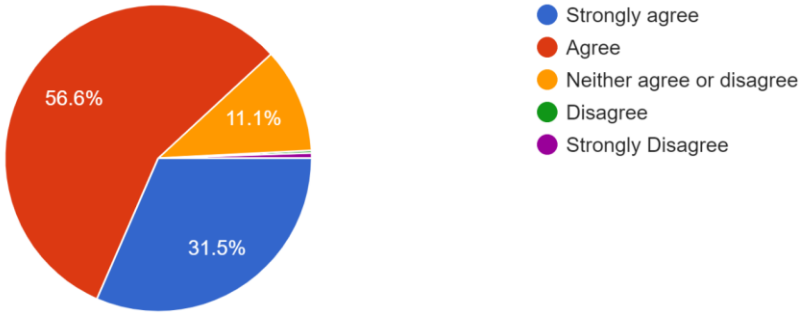
12) PACS has reduced the number of exams reordered because the exams were not available (lost or located elsewhere) when I needed them.

371 responses



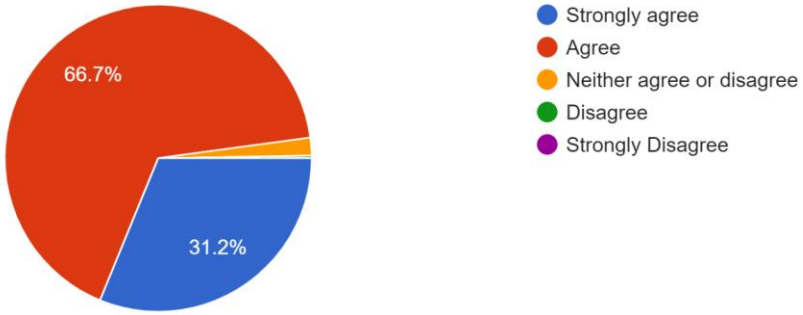
13) PACS has enhanced patient care and service delivery at Charlotte Maxeke Johannesburg Academic Hospital.

371 responses



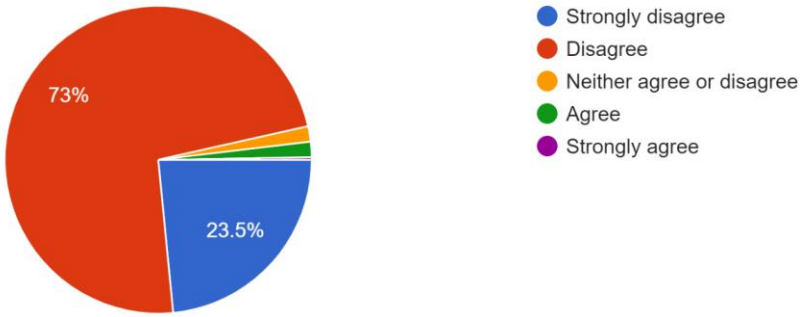
14) PACS has improved medical student/registrar teaching.

372 responses



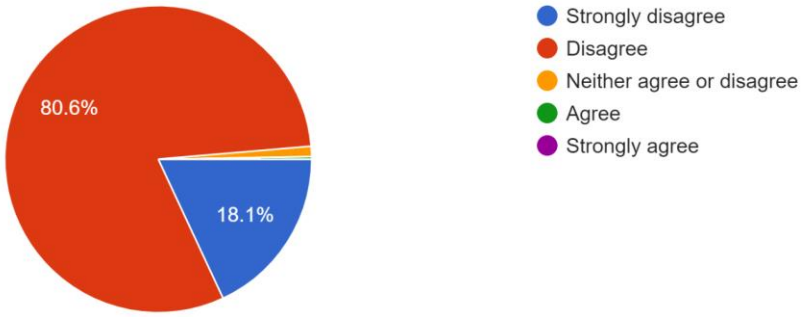
15) PACS produces inadequate image quality on our image review stations.

371 responses



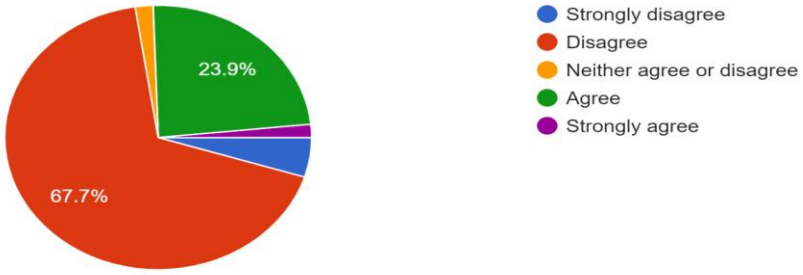
16) I have difficulty finding images/reports when needed.

371 responses



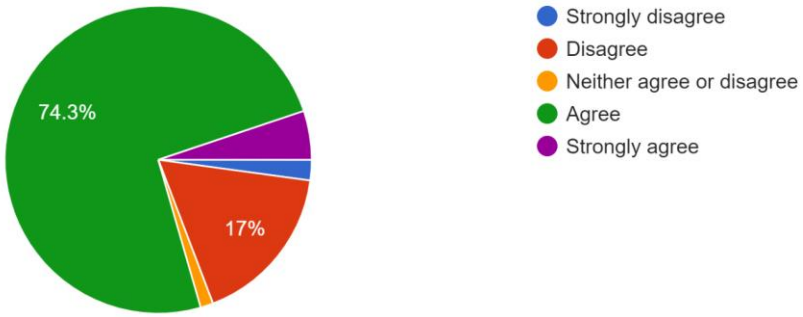
17) I experience inadequate workstation performance (Speed).

372 responses



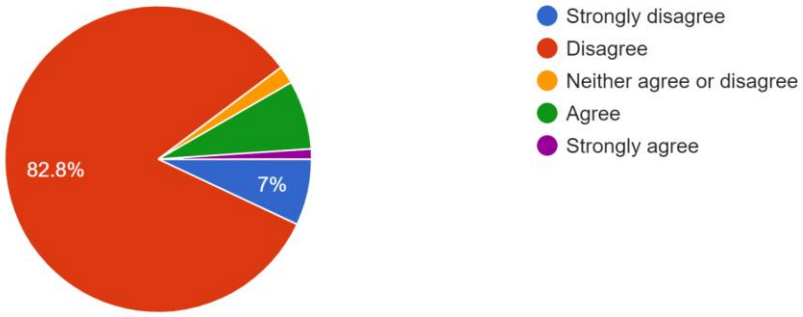
18) I have inadequate access to PACS viewing stations.

370 responses



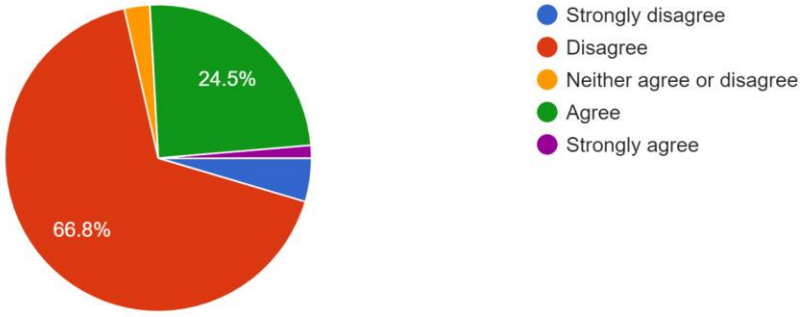
19) I have difficulty logging on to the system.

372 responses



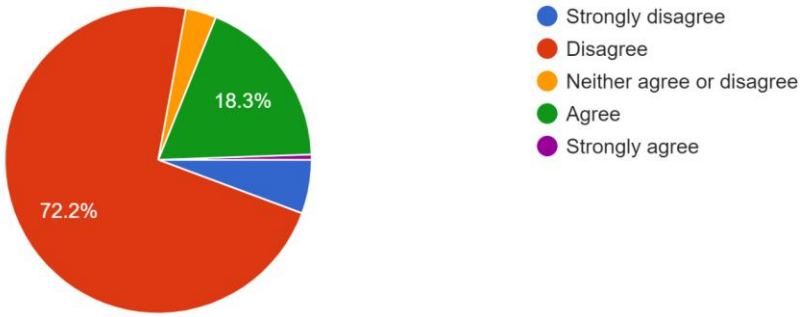
20) PACS downtime is higher than acceptable (Malfunction of system).

371 responses



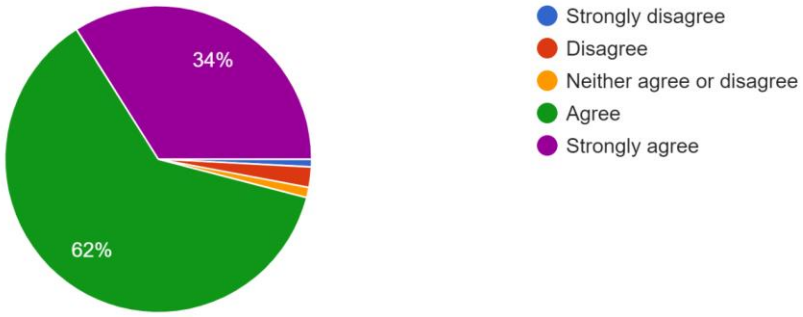
21) I have received insufficient training in this new technology.

371 responses



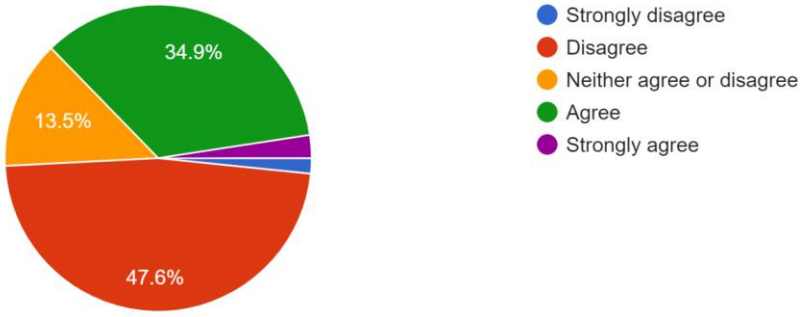
22) I am unable to view images at the patient's bedside (PC or Mobile devices).

371 responses



23) I experience a lack of availability of the system support (From PACS administrators).

370 responses



Appendix D: Note on referencing style

Please note that the referencing in this thesis is a modification of the Vancouver Referencing style, done according to the Faculty of Health Sciences Style Guide as set out by the Wits Health Sciences Library.

The information on this WHSL Vancouver Citation Style Guide for Theses, Dissertations and Research Reports is available from http://libguides.wits.ac.za/whsl-vancouver updated on 8 August 2017.