Does the picture archiving and communication system affect report turnaround time in the radiology department of King Khalid Hospital in Saudi Arabia?

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Abstract

In this paper, the impact of the picture archiving and communication system (PACS) at King Khalid Hospital (KKH) in Saudi Arabia is examined. The primary objective of the study was to establish whether PACS has benefitted KKH through a reduction in the report turnaround time (TAT). To understand its impact at KKH, a sample of 768 medical imaging reports was selected from about 100,000 reports generated in the facility. The sample was divided into two timeframes: the pre-PACS period (1st January 2017 to 30th June 2017) and that post-PACS timeframe (1st January 2018 to 30th June 2018). A quantitative research approach, using quasi-experimental design, was applied for the study to achieve the set objectives. Data analysis was primarily carried out using descriptive statistics. The overall impact of PACS was the reduction in mean report TAT, from an average of 15.139 hours pre-PACS to 7.958 hours post-installation. The decline was statistically significant at 7.181 hours, or a decrease in mean report TAT of around 47.43%. A decline in average report TAT was also recorded across three different radiology modalities (MRI, CT &US) in both inpatient and outpatient departments: (23.27 hours pre-PACS down to 12.66 hours post-PACS for outpatient MRI; 16.82 hours down to 10.30 for inpatient MRI; 20.45 hours down to 10.08 for outpatient CT; 17.61 hours down to 8.69 for inpatient CT; 07.40 hours down to 03.49 for outpatient US and 05.25 hours down to 02.49 for inpatient US). The key derivation from the study was that PACS implementation at KKH had a positive impact on report TAT. A relatively small study sample and a short adjustment period after PACS implementation were the core limitations of the study.

Introduction

Health informatics technology has become one of the key pillars for the advancement of healthcare systems to meet changing health demands (Huang, 2011; Kohli, Dreyer, & Geis, 2015; Deshmukh, Lenina, Kulkarni, & Kolharkar, 2018). The picture archiving and communication system (PACS) is a primary example of the advancement of this technology to meet healthcare demands (Peck, 2017; Seeram, 2019). Prior to the introduction of PACS, conventional film-based radiographs - an analogue system of image collection, storage, and retrieval - was used. This system was plagued by challenges such as loss of images, duplication, and low quality (Moodley & Moodley, 2015; Amarathunga et al., 2015). With the introduction of radiology technology, digital systems began to be developed in the second half of the twentieth century, culminating in the introduction of PACS (Greyling & Pitcher, 2018; Liao & Seeram, 2019). PACS can be defined as network of computers in hospital settings which facilitate the storage, retrieval, distribution, and display of medical images and data (Alhajeri, Aldosari, & Aldosari, 2017; Huang, 2019).

The use of PACS in healthcare systems has been shown to benefit users and the systems in general. Moving on from contemporary film-based systems has been shown to reduce image loss and duplication while also increasing quality (Floyd, Trepp, Ipaki, & Ng, 2015; Schooley, Hikmet, & Atilgan, 2016). Other advantages with the PACS system include increased productivity, which is measured by the imaging output for a given time within radiology departments (Forsberg, Rosipko, Sunshine, & Ros, 2016; Buabbas, Al-Shamali, Sharma, Haidar, & Al-Shawaf, 2016). Since PACS allows instantaneous access through multiple termini, it has been lauded for improving both accessibility and availability of medical images and data (Hameed, Umer, Khan, Pirani, & Yusuf, 2018; Jeyakumar & Kanagaraj, 2019). One key advantage of PACS, which is the subject of study in this paper, is its impact on report turnaround time (TAT), which has been said to reduce in radiology after implementation of PACS, and which in turn improves overall workflow and service delivery (Rathnayake, Nautsch, Goodman, Forman, & Gunabushanam, 2017). Report turnaround time TAT is defined as the period taken between a radiographic examination being completed and the report being generated by radiologists (Rosenkrantz, Bonavita, Foran, Matza, & McMenamy, 2014; England, Collins, White, Seagull, & Deledda, 2015). Report TAT is a measure of the success of PACS in healthcare settings (Pham, Forsberg, & Plecha, 2017). In this study, report TAT is assessed as a measure of the success of PACS at King Khalid Hospital in Najran, Saudi Arabia.

The primary objective of this paper is to establish whether or not the implementation of PACS has added benefits to the radiology department at KKH, specifically focussing on its effect on report TAT. The secondary objectives for the study are the assessment of the overall impact of PACS on report TAT, its impact on report TAT across the inpatient and outpatient departments, and radiology modalities (magnetic imaging resonance (MRI), computed tomography (CT) and ultrasound (US)) at KKH by comparing average values pre- and post-PACS implementation.

Previous Research

Alalawi, Eid, and Albarrak, (2016) carried out a study across three Ministry of Health hospitals in Riyadh, Saudi Arabia, which established that 70% of the 228 physicians and radiologists were in agreement that their efficiency was boosted by the PACS system and 69% agreed that their clinical decision-making abilities were enhanced by its implementation. Other studies have revealed similar results, showing that PACS contributes to increased hospital efficiency by reducing report TAT and therefore the length of stay for patients (Zaman, Sajjad, & Fatima, 2016; Ahmadi, Mehrabi, Sheikhtaheri, & Sadeghi, 2017; Sarbaz, Hosseini, & Kimiafar, 2019).

In addition, Stern, Boehm, Seifert, and Kawel-Boehm, (2018) revealed that when reporting goes from general to subspecialised, report TAT is reduced greatly, which occurs from streamlining of operations (Eigles, Panughpath, & Kalyanpur, 2015; Mendel & Schweitzerm, 2015; Rachh et al., 2018). Moreover, other studies have established a link between the high levels of productivity in PACS with reduced report TAT (Tesoriero, Eddy, & Hasso, 2015; Stern et al., 2018; Kovacs, Cho, Burchett, & Trambert, 2019). Additional studies have also examined how the key features of PACS such as instantaneous physician access to reports through the highly-networked system serves to reduce report TAT (Kessler, Stowell, Vogel, Liao, & Kendall, 2016; Stoica, Mogos, Draghici, & Cergan, 2017; Mongan & Avrin, 2018). Other studies have focused on elements such as image quality, presence of manipulation functions, reduction in image loss, and reduction in duplication of images with the reduction in report TAT when comparing PACS to conventional imaging (Drew et al., 2015; Arvanitis & Loukis, 2016; Schooley et al., 2016; Greyling & Pitcher, 2018; Awokola, Emuoyibofarhe, Meinel, & Ajala, 2019; Dahl & Huynh, 2019).

A few studies have identified issues with PACS such as delays by system failures, insufficient training and operational difficulties (van Ooijen, Aryanto, Broekema, & Horii, 2015; Valente, Silva, Godinho, & Costa, 2016; Berkowitz, Wei, & Halabi, 2018; Alhajeri & Shah, 2019), many have focused on other benefits of PACS and have in the process ignored the time-saving implications (Olthof & van Ooijen, 2016), and even those which have focused on the time-saving of PACS have not dedicated their attention to report TAT (Stern et al., 2018; Huang, 2019). As such, the current study attempts to fill this gap by exploring how report TAT is affected by a PACS framework being implemented in a hospital previously using conventional film-based systems for image collection, analysis, manipulation, reporting, and retrieval.

Study Methods

Study Setting

In Saudi Arabia, major hospitals run by the Ministry of Health (MOH) have digital radiography systems with PACS being one of the most convenient for use (Aldosari, Saddik, & Al Kadi, 2018; Alhailiy, Kench, McEntee, Brennan, & Ryan, 2018). This study was based on one of MOH's 500-bed non-profit hospitals called King Khalid Hospital (KKH) which is located in Najran, a city in the southwest of the country. KKH was among the first hospitals in the country to adopt PACS, in July 2017, where it is integrated with a variety of radiological modalities including X-ray, ultrasound (US), computed tomography (CT), magnetic resonance imaging (MRI), fluoroscopy, angiography, and mammography.

Study Design

This study uses a quantitative research approach, and relies on a quasi-experimental design to fulfil its objectives. An experimental approach is useful in that it offers accuracy in the establishment of trend patterns among variables (Myers, Well, & Lorch, 2013; Patten & Newhart, 2017; Yandell, 2017; Nardi, 2018). An experimental research design is also important in the establishment of cause-effect links with a formulated hypothesis and gives the researcher control over the chosen variables (Saks & Allsop, 2012; Johnson et al., 2013; Creswell & Creswell, 2017). In this study, a quasi-experimental design was chosen because it is the most appropriate for carrying and pre- and post-test on a given parameter (Furtak, Seidel, Iverson, & Briggs, 2012; Campbell & Stanley, 2015).

Furthermore, a quasi-experimental design allows the manipulation of the independent variable but limits the random assignment of the subjects to conditions (Furtak et al., 2012; White & Sabarwal, 2014; Kontopantelis, Doran, Springate, Buchan, & Reeves, 2015). The pre-test/post-test quasi-experimental design applied for this study allowed for the measurement of the dependent variable, report TAT, once before PACS was implemented and once afterwards. Changes in the time between the pre-test and post-test periods can be said to have occurred as a result of the implementation (Thyer, 2012; Campbell & Stanley, 2015). However, while this approach is effective for the current study, it has limitations in that it ignores other factors which may have effects (Cook, 2015; Handley, Lyles, McCulloch, & Cattamanchi, 2018).

Study Population

In research, population describes the given entities which share features and allow a uniform classification (Charan & Biswas, 2013; Binu, Mayya, & Dhar, 2014). Populations are diverse and may include people, events, nations, objects, and organisations (Creswell & Creswell, 2017). In this study, medical imaging reports generated by the radiology department at KKH are the study population, which is composed of 100,000 medical imaging reports generated at KKH in the course of the latest available internal statistics reported at KKH (1st January - 30th December 2018). The population is considered comprehensive as it includes reports from across the radiological modalities in the hospital: magnetic resonance imaging (MRI), computed tomography (CT) and ultrasound (US).

Study Sample

Study sampling is a research technique which facilitates easier analysis through the selection of an adequate representative population (Suresh & Chandrashekara, 2012; Fassinger & Morrow, 2013; Chow, Shao, Wang, & Lokhnygina, 2017; Machin, Campbell, Tan, & Tan, 2018). Since this study employs a quantitative research approach, a technique called "power calculation" was deemed the most appropriate for generation of an adequate sample that would represent the study population of 100,000 medical imaging reports effectively (Binu et al., 2014; de Bekker-Grob, Donkers, Jonker, & Stolk, 2015; Etikan, Musa, & Alkassim, 2016). The term power is used interchangeably with sample size. Power calculation provides researchers with a means to calculate the number of subjects required to answer the given research question while avoiding sampling errors (Martínez-Mesa, González-Chica, Bastos, Bonamigo, & Duquia, 2014; Machin et al., 2018). Using the power calculation approach, it was established that 383 was the minimum number of imaging reports in each period exhibited a 95% confidence level (Appendix I.). Therefore, 384 imaging reports relating to the six months before PACS installation (1st January 2017 to 30th June, 2017) and 384 reports relating to the six months after (1st January 2018 to 30th June, 2018) were used.

Data Collection

For this study, report TAT was defined as the period between when a patient radiology examination was completed and when an imaging report was generated (England et al., 2015; Coleman, Holalkere, Doherty, Norbash, & Kadom, 2016; Hitti et al., 2017). In both periods, report TAT was calculated since a time log is maintained between examination completion and report release (Forsberg, Rosipko, & Sunshine, 2016).

Data collection was segmented into two portions in order to meet the objective of detecting the impact of PACS implementation on report TAT in KKH. In order to fulfil this objective, the study had to capture report TAT before and after PACS implementation. Between 2013 and 2017, the radiology department of KKH used a Radiology Information System (RIS) as its primary operating system for management, which is composed of networked systems which facilitate the management of medical images through tracking orders, billing data, and record management (Aldosari, 2012; Peck, 2017). In July 2018, PACS was implemented and integrated with the RIS.

Hence, the data used in this study was collected from RIS databases in KKH's radiology department in the same calendar period before PACS installation (1st January 2017 to 30th June, 2017) and afterwards (1st January 2018 to 30th June, 2018), to ensure consistency of results. A training period of six months (July to December 2017) divided the two timeframes, and was put in place to ensure that the users of the new technology became acquainted with its operations (Kovacs et al., 2019; Yepes-Calderon, Bluml, Erberich, Nelson, & McComb, 2019). However, any relevant events that might have happened during this break were not incorporated in this study.

The inclusion criteria for imaging reports were that they had to be generated from three modalities: magnetic resonance imaging (MRI), computed tomography (CT) and ultrasound (US). Moreover, the imaging reports that were included in the study had to relate to both inpatient and outpatient departments of the hospital. Only adult reports were included in the study, and they had to have been cleared by the radiologist and have their name and stamp. Imaging reports excluded from the study included imaging reports from other modalities, since the policy of The Saudi Arabian Ministry of Health does not allow imaging reports to be generated for general cases such as for X-rays except in death or criminal cases (Aldosari, 2014). Data from departments other than inpatient and outpatient was also excluded, along with reports generated from other hospitals since the purpose was to analyse the impact of PACS on report turnaround time at KKH.

Ethical Considerations

In order fulfil the purpose of the study, certain ethical considerations had to be made. Before beginning the study, approval was sought from the ethics committee of the Saudi MOH (Appendices II. and III.). The researcher was familiarised with the rules, regulations and code of ethics which govern research from both ethics committees and signed against each. The key ethical requirements adhered to during the study included those surrounding privacy, integrity, honesty and transparency in reporting (Hartas, 2015; Patten & Newhart, 2017; Creswell & Creswell, 2017).

Reporting of the data collected was honest and not doctored to fall into the researcher's planned outcomes (Larson- Hall & Plonsky, 2015; Ary, Jacobs, Irvine, & Walker, 2018; Wallach, Gonsalves, & Ross, 2018; Bhui, Lee, Kaufman, & Lawrie, 2019). The approval from the management of KKH was subject to an agreement on certain ethical issues pertaining to ethical conduct and patient care policy (Hammersley, 2015). For instance, data collection was not permitted to in any way interfere with the normal processes of healthcare delivery in the hospital (Ienca et al., 2018). Additionally, the researcher was required to adhere to time schedules to avoid inconveniencing the radiology department staff at the hospital (Ienca et al., 2018). Throughout the research period at KKH, all ethical protocols were duly observed by the researcher and no ethical conflicts arose.

Data Analysis

The data collected from both the pre- and post-PACS implementation frames was summarised and used as numeric data. The primary technique used in the analysis of the data in this study was descriptive statistics (Chatfield, 2018). As a method of data analysis, descriptive statistics provided the researcher with an avenue to create a numerical description of the given population based on the chosen common characteristics and provided a viable link between sample characteristics and answering of the research question (Creswell & Creswell, 2017; Chatfield, 2018). In the case of this study, the characteristics presented by the 768 image reports were easily linked to answer the formulated research question using descriptive statistics. Hence, the use of descriptive statistics offered the advantage of simple and efficient depiction of distribution results and comparative analysis (Heeringa, West, & Berglund, 2017).

Since data was collected in two distinct timeframes, efficient analysis was performed through the use of tables and charts for certain sets of data. The data had been collected using the Microsoft Excel tool. The Statistics Package for Social Sciences (SPSS) version 25 was utilised to generate analysis sets for the data (Babbie, Wagner III, & Zaino, 2018), which facilitated the generation of data output in the form of tables and charts and comparative analysis of the data collected for the period before implementation of PACS and afterwards (Loewen & Gonulal, 2015). SPSS has the advantage of providing comprehensive tools for plotting, reporting, and presentation of data (Babbie et al., 2018). Average values were calculated and compared for each timeframe in order to analyse for any significant changes (Babbie et al., 2018). Regression and correlation analysis were used to depict the impact and its movement concerning report TAT, respectively.

Results

Three-way-ANOVA Test

In order to answer the research question, an ANOVA t-test analysis was carried out. This was deemed to be the most reliable because of the presence of multiple variables which affected the dependable variable, report TAT. This analysis was based on three factors: the change in overall report TAT between the pre- and post-PACS periods; the type of departments (inpatient or outpatient); and the type of radiographic modalities (MRI, CT, US). The interest in these factors was to assess whether they had a role to play in the reduction of report TAT.

The ANOVA t-test, as shown in Table 1, established a significant difference in the report TAT during the two periods (p-value= 0.00 < 0.05) for the main effect of PACS, meaning that the effect of post-PACS on report TAT is significantly different from pre-PACS. The difference between the two periods across the outpatient and inpatient departments was also significant: (p-value= 0.011 < 0.05). In the three modalities, the ANOVA test established a significant difference between the two periods with regard to the impact of PACS: (p-value= 0.00 < 0.05). In addition, the differences were significant in report TAT between the types of departments and the modalities types: (p-value= 0.02 < 0.05). However, the table also shows a non-significant difference in report TAT between the all three factors: (p-value = 0.323 > 0.05). The ANOVA test findings validate the research objectives by showing a significant reduction in report TAT after the implementation of PACS in the radiology department of KKH.

Tests of Between-Subjects Effects					
Dependent Variable: Report turnaround time					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	32888,154ª	11	2989,832	82,479	,000
Intercept	101149,000	1	101149,000	2790,336	,000
Main effect of PACS	9776,716	1	9776,716	269,704	,000
Main effect of departments	1380,330	1	1380,330	38,078	,000
Main effect of modalities	18307,110	2	9153,555	252,514	,000
PACS * departments	235,417	1	235,417	6,494	,011
PACS * modalities	1445,150	2	722,575	19,933	,000
departments * modalities	284,229	2	142,115	3,920	,020
PACS * departments * modalities	81,990	2	40,995	1,131	,323
Error	27404,812	756	36,250		
Total	163529,899	768			
Corrected Total	60292,966	767			
a. R Squared = ,545 (Adjusted R Squared = ,539)					

Table 1: Three-way-ANOVA t-test for the report TAT with multiple variables

MRI Modality

MRI scanning is one of the major modalities in the radiology department at KKH. Figure 1 compares the MRI scan average report TAT for both outpatient and inpatient departments, both pre- and post-PACS implementation. In the period prior to the implementation of PACS, it can be seen that average report TAT for an MRI scan in the outpatient department was 23.27 hours, but was reduced to 12.66 hours after the PACS system was implemented. For the pre-PACS period in the inpatient department, average report TAT was 16.82 hours and was reduced to 10.30 hours post-PACS. On average, the outpatient department experienced a significant reduction in MRI report TAT of (23.27 - 12.66) = 10.61 hours, which indicates a reduction of (10.61 / 23.27) * 100 = 45.59% between pre- and post-PACS implementation. In the inpatient department, the average reduction in MRI report TAT showed a reduction of (16.82 - 10.30) = 6.52

hours, which indicates a reduction of (6.52 / 16.82) * 100 = 38.76% between the two timeframes.

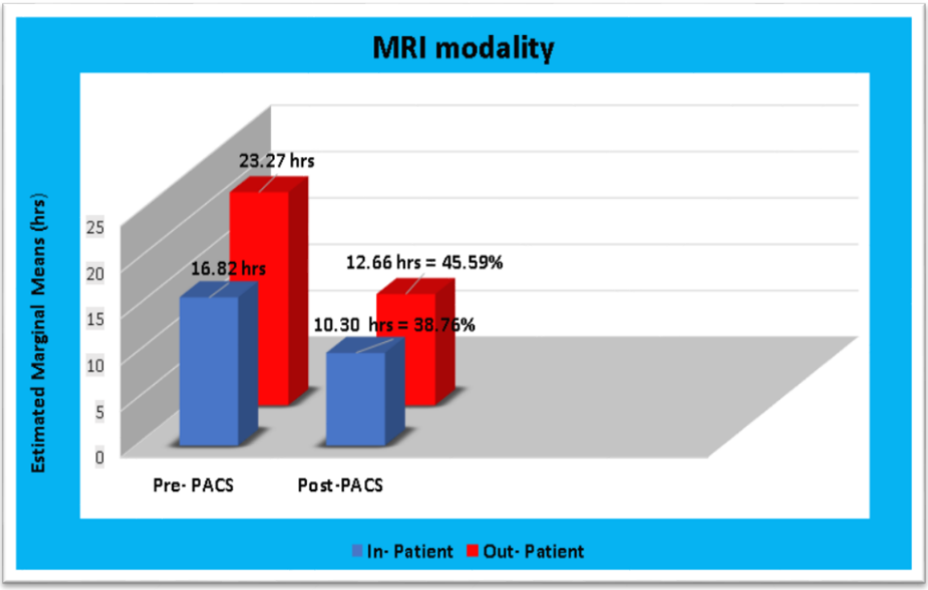


Figure 1: Estimated marginal means (hours & percentage) of report TAT for the MRI modality

CT Modality

Computed Tomography (CT) imaging is of central importance in the radiology department of KKH and reducing its report TAT was considered a success measure by management, as it indicates faster delivery of healthcare services. Figure 2 below represents a comparison of the CT scan average report TAT for outpatient and inpatient departments, both pre- and post-PACS implementation. This figure shows that the implementation of PACS greatly reduced the mean report TAT for both outpatient and inpatient departments. For outpatients, the average report TAT for a CT scan was 20.45 hours before PACS, but reduced to 10.08 hours after the system was implemented. This change represented a reduction of (20.45 - 10.08) = 10.37 hours on average for a CT scan which represents a decrease of (10.37 / 20.45) * 100 = 50.70% between the two timeframes. Inpatients saw the average report TAT reduce from 17.61 hours pre-PACS to 8.69 hours post-PACS. This change indicated a reduction of (17.61 - 8.69) = 8.92 hours which represents a decrease (8.92 / 17.61) * 100 = 50.65% in average report TAT for inpatient CT scans when comparing pre- and post-PACS timeframes.

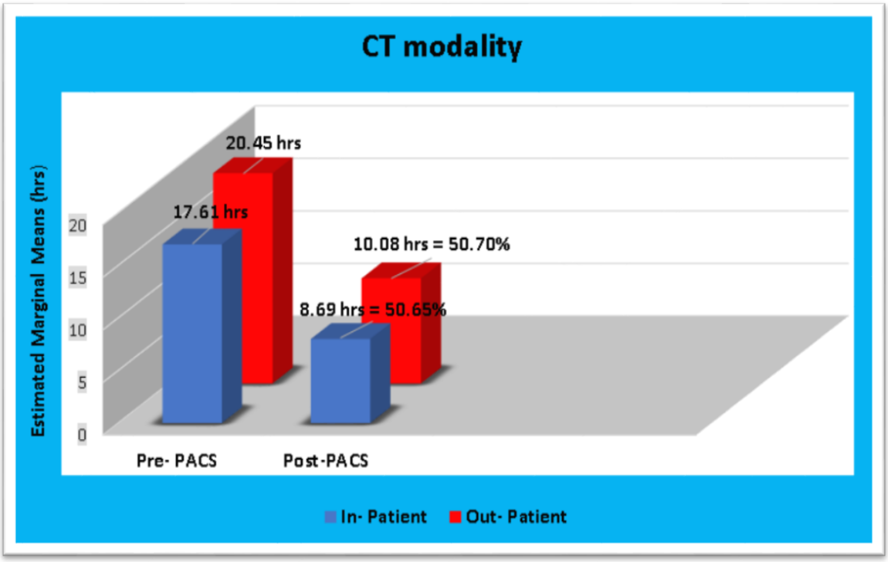


Figure 2: Estimated marginal means (hours & percentage) of report TAT for the CT modality

US Modality

Figure 3 below represents a comparison of the US modality average report TAT for outpatient and inpatient departments, both pre- and post-PACS implementation. This was also affected significantly after the implementation of PACS in KKH, with a reduction in average report TAT after the implementation of PACS in both the outpatient and inpatient departments. In outpatients, average report TAT was reduced from 7.40 hours to 3.49 hours after the implementation of PACS. This change represents a reduction of (7.40 - 3.49) = 3.91 hours on average for a US scan which represents a decrease of (3.91 / 7.40) * 100 = 52.83% between the two timeframes. In the inpatient department, average report TAT was reduced to 2.49 hours from 5.25 hours after the implementation of PACS. The reduction in average report TAT for the US modality was (5.25 - 2.49) = 2.76 hours which represents a decrease of (2.76 / 5.25) * 100 = 52.57%.

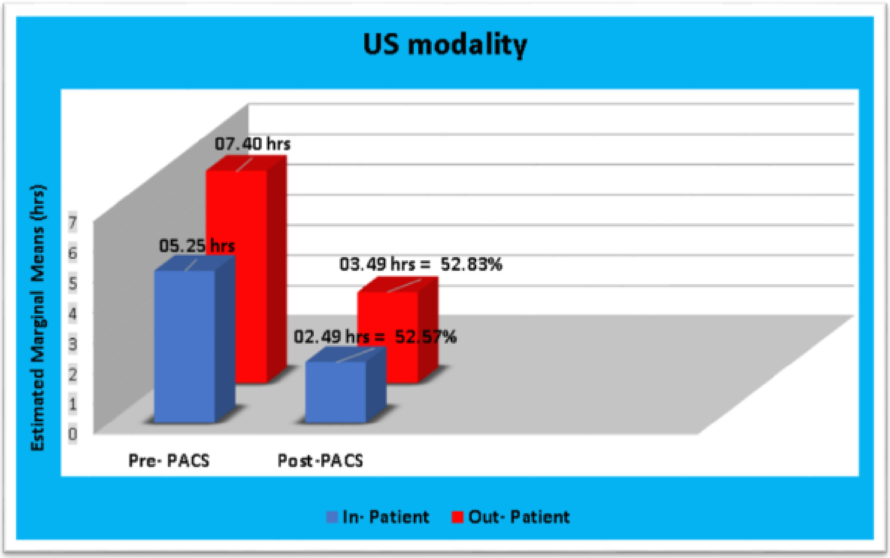
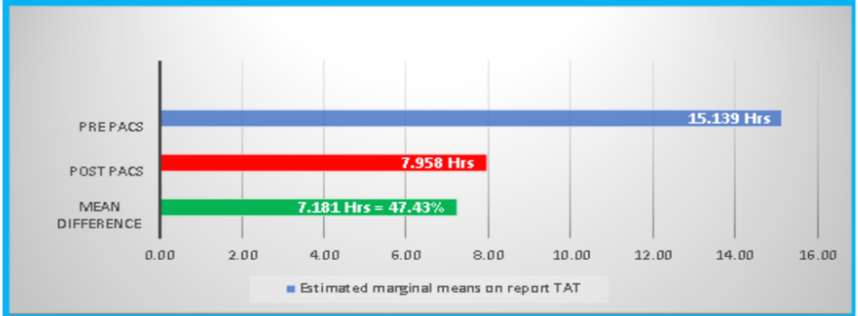


Figure 3: Estimated marginal means (hours & percentage) of report TAT for the US modality

Overall Changes in Report TAT

Figure 4 below presents the overall mean report TAT through ANOVA t-test in pre-and post-PACS timeframes across all modalities in both departments, showing the mean difference by hours and percentage. The overall report TAT was successfully improved by decreasing report TAT from a mean of 15.139 hours to 7.958 hours after PACS, which represents a drop in mean report TAT of around 47.43%. This reduction was achieved by factoring in the impact noticed across the three modalities tested in this study in both outpatient and inpatient departments.



Estimated marginal means (Pre and Post PACS)

Dependent Variable: Report turnaround time				
			95% Confidence Interval	
Pre and Post PACS	Mean	Std. Error	Lower Bound	Upper Bound
Pre-PACS	15.139	.309	14.532	15.746
Post-PACS	7.958	.309	7.351	8.565
Mean Difference	7.181 = 47.43% (Significant)			

Figure 4: Estimated marginal means (hours + percentage) of report TAT in (pre- post-PACS)

Discussion

In this study, a comparison of mean values between pre- and post-PACS implementation has established that report TAT reduced significantly at KKH. Between 1st January and 30th June 2017, King Khalid Hospital (KKH) was using a conventional film-based framework and the average report TAT was 15.139 hours. Soon after PACS was adopted, the average report TAT between 1st January 2018 and 30th June 2018 was just 7.958 hours. Therefore, average report TAT between the pre- and post-PACS timeframes declined by 7.181 hours (a decrease of 47.43%) which confirms the positive claims for the implementation of PACS in healthcare facilities (Aldosari, 2014; McDonald et al., 2015; Buabbas et al., 2016; Alhajeri et al., 2017; Deshmukh et al., 2018). Moreover, the reduction in report TAT occurred across the outpatient and inpatient departments and the different radiographic modalities (magnetic imaging resonance (MRI), computed tomography (CT) and ultrasound (US)), which is a clear indication of the positive impact of PACS on report TAT.

The findings from this study are a reinforcement of similar findings from previous studies which have examined report TAT within the PACS framework. In one relevant study by Georgiou et al. (2015), which examined a 750-bed hospital in Sydney, Australia, it was found that introducing a new PACS decreased report TAT from 78 hours to 38 hours for patients released from the emergency department (ED) and from 84 hours to 35 hours for inpatients. This reduction, as explained by medical staff who were interviewed in the study, resulted from increased efficiency in operations and improved access to images and patient data (Georgiou et al., 2015). Such findings are similar to those in this study, where the average report TAT was reduced by almost half (47.43%) when PACS was adopted in the radiology department at KKH.

Moodley and Moodley (2015) carried out a time and motion study to calculate the time taken to capture a patient's data and the production of the final report (report TAT), which examined report TAT for PACS versus a conventional radiology system. The findings were similar to that of this study, in that it established that by using PACS, the time taken for patients to get their reports for chest radiographs, CT brain scans, and MRI brain scans was greatly reduced by almost 50%. These findings correlate positively to those of this study where report TAT was reduced by 47.43% while those for MRI and CT scans were reduced by 45.59% and 50.70% for outpatients, and 38.76% and 50.65 for inpatients.

In contrast, the findings from this study also establish that across the three modalities, US scan has the lowest average report TAT while MRI and CT scans took longer to report. After PACS installation, report TAT for MRI scans was 12.66 hours for outpatients and 10.30 for inpatients; for CT scans was 10.08 hours for outpatients and 8.69 for inpatients; and for US scans was 3.49 hours for outpatients and 2.49 for inpatients. Albrecht et al. (2013) reported similar findings, where the turnaround times were shortest for the US scan when compared to other modalities such as MRI, CT, X-ray, and angiography. The longer average report TAT for MRI and CT scans in this KKH study may be attributed to the complexity of such imaging, the number of images that have to be assessed before a diagnosis is made, and the need for consultations from other radiologists or physicians in complex situations (Nie et al., 2017; Ganeshan et al., 2018). The study also revealed that in some cases, more images have to be taken for MRI and CT scans to improve diagnosis, which may explain the longer report TAT when compared to US scans.

Findings from other studies have examined the processes behind the reduction of report TAT when PACS is implemented. According to Alalawi et al. 2016, Alhajeri et al. 2017 and Bahador, Sharifian, and Farmani, (2017), improvement in report TAT as a result of PACS implementation results from processes such as enhancement of clinical decision-making, reduction in diagnostic delays, improving communication and collaboration among healthcare professionals, increasing accessibility of medical reports and boosting the overall performance of radiology departments and hospitals. Other factors that may be associated with the improvement of report TAT at KKH after the implementation of PACS include less image loss and duplication, higher quality of images and a streamlined workflow which enhances productivity (Nitrosi et al., 2015, Tabatabaei, Langarizadeh, & Tavakol, 2017; Desai, Flanders, & Zoga, 2018; Kovacs et al., 2019).

While PACS has been credited with improving report TAT, previous studies have raised issues that that need to be addressed. Firstly, perceptions about the performance of PACS are not uniform among physicians and radiologists (Floyd et al., 2015; Parikh & Mehta, 2015) and while some have lauded the system for its efficiency, others have criticised it for usability issues (Deimazar, Kahouei, Norouzian, & Moslemi, 2017; Berkowitz et al., 2018; Khajouei, Jahromi, & Ameri, 2019). PACS are simplified for better usability among radiologists and physicians as far as possible. However, perceptions of usability vary and some find it cumbersome, prone to error, and difficult to use (Aldosari, 2012, 2014; Alhajeri & Shah, 2019). Other professionals have complained that the system adds additional burdens to their job descriptions and as such are in favour of the old film-based systems (Buabbas et al., 2016; Berkowitz et al., 2018; Waite et al., 2018).

The recommendation from several studies has been that PACS developers need to consider user challenges (Parikh & Mehta, 2015; Zahiri, Farokhzadian, Bahaadinbeigy, & Khajouei, 2019). Additionally, training has emerged as one of the core solutions to the usability challenges for PACS in healthcare facilities (Al-Hajeri & Clarke, 2015; Doshi et al., 2018).

At KKH, a six-month period was used for staff training during which they were familiarised with the PACS system. However, PACS training should be given as a continuous process where staff are trained on its various aspects of use such as image retrieval and analysis and the retrieval of reports. Also, the incorporation of current technology in PACS has been credited with improving report TAT. Prevedello, Ledbetter, Farkas, and Khorasani, (2014) found out that when speech recognition software was used as part of the PACS system to facilitate radiologists' oral dictation of reports, it led to a 24-fold improvement in report TAT.

Going forward, more research needs to be conducted on the impact of PACS frameworks and report TAT. There are still gaps such as the identifying the exact mechanisms through which PACS lowers report TAT (Wildman-Tobriner et al., 2019), as research has concentrated on establishing whether or not PACS lowers report TAT rather than establishing how that benefit occurs (Lazar, 2019). In addition, PACS appears to affect report TAT differently as function of radiology modalities (Stern et al., 2018). More research needs to be carried out to establish the cause of differences between the varied degrees of PACS impact on report TAT and look for means to confer uniformity.

Limitations of the Study

The current study was faced with a number of limitations which affect the implications of the findings. To start with, the waiting period after the implementation of PACS may not have been adequate for familiarisation with the new system though training. PACS is a complex system when compared to the conventional imaging system used prior to its implementation (Alhajeri et al., 2017). Moreover, the sample size of 768 reports out of more than 100,000 generated each year might not represent the population properly (Creswell & Creswell, 2017). While this sample fell within a 95% confidence level, it might be problematic to extrapolate the sample to cover an entire country, though they do have positive implications for KKH. As such, a study with a wider sample would create more certainty (Binu et al., 2014). The last limitation is that the study did not account for common complications within radiology departments, such as human error and system downtimes, which have been shown to affect report TAT immensely. Usability challenges tend to be manifested through malfunctions and human error which then prolong the report TAT for PACS (Berkowitz et al., 2018).

Conclusion

This study validates the hypothesis that when PACS frameworks are implemented in radiology departments to replace conventional film-based systems, report TAT is successfully improved, in this case by about 47.43%. The implications from this study and others which have shown similar results is that more hospitals need to adopt PACS as a step towards the improvement of report TAT that contributes to efficient healthcare delivery. A significantly improved report TAT in radiology is considered a key performance indicator as it translates to speed of diagnosis, treatment and length of stay for patients, as well as an indicator of efficiency in operations. Therefore, more research needs to take place regularly in radiology departments, to measure PACS influence on report TAT and further increase its efficiency.

The effect of PACS implementation on average report TAT in this study is a decrease of around 47.43% which is still not optimal for efficient diagnosis and treatment. Since some studies in this study have identified pertinent issues with PACS such as usability difficulties, therefore more attention needs to be focused on solving these challenges. For instance, training needs to be implemented in hospitals for radiologists, physicians, and other medical staff interacting with the technology to facilitate better usability.

References

Ahmadi, M., Mehrabi, N., Sheikhtaheri, A., & Sadeghi, M. (2017). Acceptability of picture archiving and communication system (PACS) among hospital healthcare personnel based on a unified theory of acceptance and use of technology. Electronic physician, 9(9), 5325. DOI: 10.19082/5325

Alalawi, Z. M., Eid, M. M., & Albarrak, A. I. (2016). Assessment of picture archiving and communication system (PACS) at three of ministry of health hospitals in Riyadh region–Content analysis. Journal of infection and public health, 9(6), 713-724. DOI: 10.1016/j.jiph.2016.09.004

Albrecht, L., Busse, R., Tepe, H., Poschmann, R., Teichgräber, U., & Hamm, B. (2013). Turnaround time for reporting results of radiological examinations in intensive care unit patients: an internal quality control. Der Radiologe, 53(9), 810-816. DOI: 10.1007/s00117-013-2537-y

Aldosari, B. (2012). User acceptance of a picture archiving and communication system (PACS) in a Saudi Arabian hospital radiology department. BMC medical informatics and decision making, 12(1), 44. DOI: 10.1186/1472-6947-12-44

Aldosari, B. (2014). Rates, levels, and determinants of electronic health record system adoption: A study of hospitals in Riyadh, Saudi Arabia. International journal of medical informatics, 83(5), 330-342. DOI: 10.1016/j.ijmedinf.2014.01.006

Aldosari, H., Saddik, B., & Al Kadi, K. (2018). Impact of picture archiving and communication system (PACS) on radiology staff. Informatics in Medicine Unlocked, 10, 1-16. DOI: 10.1016/j.imu.2017.11.001

Alhailiy, A. B., Kench, P. L., McEntee, M. F., Brennan, P. C., & Ryan, E. A. (2018). Establishing diagnostic reference levels for cardiac computed tomography angiography in Saudi Arabia. Radiation protection dosimetry, 181(2), 129-134. DOI: 10.1093/rpd/ncx306

Al-Hajeri, M., & Clarke, M. (2015, August). Future trends in picture archiving and communication system (PACS). In 2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC) (pp. 6844-6847). IEEE. DOI: 10.1109/EMBC.2015.7319965

Alhajeri, M., & Shah, S. G. S. (2019). Limitations in and Solutions for Improving the Functionality of Picture Archiving and Communication System: an Exploratory Study of PACS Professionals' Perspectives. Journal of digital imaging, 32(1), 54-67. DOI: 10.1007/s10278-018-0127-2

Alhajeri, M., Aldosari, H., & Aldosari, B. (2017). Evaluating latest developments in PACS and their impact on radiology practices: a systematic literature review. Informatics in Medicine Unlocked, 9, 181-190. DOI: 10.1016/j.imu.2017.08.005

Amarathunga, S. D. D., Jayasundara, P. P. A. S., Somaweera, E. G. P. P., Weerasena, P. D. C., Pulasinghe, K., & Samarathunga, S. A. (2015). Picture Archiving and Communications System (PACS) for Government Hospitals in Sri Lanka. Conference Paper: Sri Lanka Institute of Information Technology. Retrieved from https://www.researchgate.net/publication/303330366_Picture_Archiving_and_Communications_System_PACS_for_Government_Hospitals_in_Sri_Lanka

Arvanitis, S., & Loukis, E. N. (2016). Investigating the effects of ICT on innovation and performance of European hospitals: an exploratory study. The European Journal of Health Economics, 17(4), 403-418. DOI: 10.1007/s10198-015-0686-9

Ary, D., Jacobs, L. C., Irvine, C. K. S., & Walker, D. (2018). Introduction to research in education. Cengage Learning.

Awokola, J. A., Emuoyibofarhe, J. O., Meinel, C., & Ajala, F. A. (2019). Performance Evaluation of a Cloud-Based Picture Archiving and Communication System (PACS). Annals. Computer Science Series, 17(1). Retrieved from http://anale-informatica.tibiscus.ro/download/lucrari/17-1-12-Awokola.pdf

Babbie, E., Wagner III, W. E., & Zaino, J. (2018). Adventures in social research: Data analysis using IBM SPSS statistics. Sage Publications.

Bahador, F., Sharifian, R., & Farmani, A. (2017). The assessment of Picture Archiving and Communication System based on Canadian Infoway PACS Opinion Survey in Teaching Hospitals of Shiraz University of Medical Sciences. Journal of Health Management and Informatics, 4(4), 120-124. Retrieved from http://jhmi.sums.ac.ir/index.php/JHMI/article/view/415/133

Berkowitz, S. J., Wei, J. L., & Halabi, S. (2018). Migrating to the modern PACS: Challenges and opportunities. RadioGraphics, 38(6), 1761-1772. DOI: 10.1148/rg.2018180161

Bhui, K. S., Lee, W., Kaufman, K. R., & Lawrie, S. M. (2019). Ensuring research integrity: setting standards for robust and ethical conduct and reporting of research. The British Journal of Psychiatry, 215(1), 381-382. DOI: 10.1192/bjp.2019.109

Binu, V. S., Mayya, S. S., & Dhar, M. (2014). Some basic aspects of statistical methods and sample size determination in health science research. Ayu, 35(2), 119. DOI: 10.4103/0974-8520.146202

Buabbas, A. J., Al-Shamali, D. A., Sharma, P., Haidar, S., & Al-Shawaf, H. (2016). Users' perspectives on a Picture Archiving and Communication System (PACS): an in-depth study in a teaching hospital in Kuwait. JMIR Medical Informatics, 4(2), 21-34. DOI: 10.2196/medinform.5703

Campbell, D. T., & Stanley, J. C. (2015). Experimental and quasi-experimental designs for research. Ravenio Books.

Charan, J., & Biswas, T. (2013). How to calculate sample size for different study designs in medical research? Indian journal of psychological medicine, 35(2), 121. DOI: 10.4103/0253-7176.116232

Chatfield, C. (2018). Statistics for technology: a course in applied statistics. Routledge.

Chow, S. C., Shao, J., Wang, H., & Lokhnygina, Y. (2017). Sample size calculations in clinical research. Chapman and Hall/CRC.

Coleman, S., Holalkere, N. S., Doherty, G., Norbash, A., & Kadom, N. (2016). Radiology 24/7 in-house attending coverage: do benefits outweigh cost?. Current problems in diagnostic radiology, 45(4), 241-246. DOI: 10.1067/j.cpradiol.2016.02.007

Cook, T. D. (2015). Quasi- experimental design. Wiley Encyclopedia of Management, 1-2. DOI: 10.1002/9781118785317.weom110227

Creswell, J. W., & Creswell, J. D. (2017). Research design: Qualitative, quantitative, and mixed methods approaches. Sage publications.

Dahl, D. W., & Huynh, P. T. (2019). Breast radiologists: extenders of primary care. Journal of Breast Imaging, 1(1), 43-46. DOI: 10.1093/jbi/wby017

de Bekker-Grob, E. W., Donkers, B., Jonker, M. F., & Stolk, E. A. (2015). Sample size requirements for discrete-choice experiments in healthcare: a practical guide. The Patient-Patient-Centered Outcomes Research, 8(5), 373-384. DOI: 10.1007/s40271-015-0118-z

Deimazar, G., Kahouei, M., Norouzian, Y., & Moslemi, M. (2017). Evaluation of Usability of Picture Archiving and Communication System (PACS) in Clinical Settings Based on ISO 9241/10 from the Perspective of End Users. Pharmacophore, 8(6).

Desai, V., Flanders, A., & Zoga, A. C. (2018, November). Leveraging technology to improve radiology workflow. In Seminars in musculoskeletal radiology (Vol. 22, No. 05, pp. 528-539). Thieme Medical Publishers. DOI: 10.1055/s-0038-1673385

Deshmukh, V., Lenina, S. V. B., Kulkarni, M., & Kolharkar, M. S. (2018). PACS: An Overview of the Technology and Related Issues. International Journal of Engineering Technology Science and Research, 5(5), 122-128. Retrieved from https://www.researchgate.net/profile/Dr_Svb/publication/327222366_PACS_An_Overview_of_the_Technology_and_Related_Issues/links/5b8141bc299bf1d5a726fabb/PACS-An-Overview-of-the-Technology-and-Related-Issues.pdf

Doshi, A. M., Moore, W. H., Kim, D. C., Rosenkrantz, A. B., Fefferman, N. R., Ostrow, D. L., & Recht, M. P. (2018). Informatics solutions for driving an effective and efficient radiology practice. RadioGraphics, 38(6), 1810-1822. DOI: 10.1148/rg.2018180037

Drew, T., Aizenman, A. M., Thompson, M. B., Kovacs, M. D., Trambert, M., Reicher, M. A., & Wolfe, J. M. (2015). Image toggling saves time in mammography. Journal of Medical Imaging, 3(1), 011003. DOI: 10.1117/1.JMI.3.1.011003

Eigles, S., Panughpath, S. G., & Kalyanpur, A. (2015). Enhancing turn-around-time (TAT) on stroke protocol head CT reports via continuous quality improvement (CQI) methodology in a busy teleradiology practice. American Journal of Experimental and Clinical Research, 2(2), 102-104. Retrieved from http://ajecr.org/index.php/ajecr/article/view/44/117

England, E., Collins, J., White, R. D., Seagull, F. J., & Deledda, J. (2015). Radiology report turnaround time: effect on resident education. Academic radiology, 22(5), 662-667. DOI: 10.1016/j.acra.2014.12.023

Etikan, I., Musa, S. A., & Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. American journal of theoretical and applied statistics, 5(1), 1-4. DOI: 10.11648/j.ajtas.20160501.11

Fassinger, R., & Morrow, S. L. (2013). Toward best practices in quantitative, qualitative, and mixed-method research: A social justice perspective. Journal for Social Action in Counseling & Psychology, 5(2), 69-83. Retrieved from https://openjournals.bsu.edu/jsacp/article/view/491

Floyd, D. M., Trepp, E. R., Ipaki, M., & Ng, C. K. (2015). Study of radiologic technologists' perceptions of Picture Archiving and Communication System (PACS) competence and educational issues in Western Australia. Journal of digital imaging, 28(3), 315-322. DOI: 10.1007/s10278-014-9765-1

Forsberg, D., Rosipko, B., & Sunshine, J. L. (2016). Analyzing PACS usage patterns by means of process mining: Steps toward a more detailed workflow analysis in radiology. Journal of digital imaging, 29(1), 47-58. DOI: 10.1007/s10278-015-9824-2

Forsberg, D., Rosipko, B., Sunshine, J. L., & Ros, P. R. (2016). State of integration between PACS and other IT systems: a national survey of academic radiology departments. Journal of the American College of Radiology, 13(7), 812-818. DOI: 10.1016/j.jacr.2016.01.018

Furtak, E. M., Seidel, T., Iverson, H., & Briggs, D. C. (2012). Experimental and quasi-experimental studies of inquiry-based science teaching: A meta-analysis. Review of educational research, 82(3), 300-329. DOI: 10.3102/0034654312457206

Ganeshan, D., Duong, P. A. T., Probyn, L., Lenchik, L., McArthur, T. A., Retrouvey, M., ... & Francis, I. R. (2018). Structured reporting in radiology. Academic radiology, 25(1), 66-73. DOI: 10.1016/j.acra.2017.08.005

Georgiou, A., Prgomet, M., Lymer, S., Hordern, A., Ridley, L., & Westbrook, J. (2015). The impact of a health IT changeover on Medical Imaging Department work processes and turnaround times. Applied clinical informatics, 6(03), 443-453. DOI: 10.4338/ACI-2015-01-RA-0014

Greyling, A. G. W., & Pitcher, R. D. (2018). Who PACS a Punch? The Role of the Picture Archiving and Communication System/Radiology Information System (PACS/RIS) in Quantifying Experiential Learning in Radiology Residency. Journal of digital imaging, 31(6), 792-798. DOI: 10.1007/s10278-018-0106-7

Hameed, M. H., Umer, F., Khan, F. R., Pirani, S., & Yusuf, M. (2018). Assessment of the diagnostic quality of the digital display monitors at the dental clinics of a university hospital. Informatics in Medicine Unlocked, 11, 83-86. DOI: 10.1016/j.imu.2018.02.002

Hammersley, M. (2015). On ethical principles for social research. International Journal of Social Research Methodology, 18(4), 433-449. DOI: 10.1080/13645579.2014.924169

Handley, M. A., Lyles, C. R., McCulloch, C., & Cattamanchi, A. (2018). Selecting and improving quasi-experimental designs in effectiveness and implementation research. Annual review of public health, 39, 5-25. DOI: 10.1146/annurev-publhealth-040617-014128

Hartas, D. (Ed.). (2015). Educational research and inquiry: Qualitative and quantitative approaches. Bloomsbury Publishing.

Heeringa, S. G., West, B. T., & Berglund, P. A. (2017). Applied survey data analysis. Chapman and Hall/CRC.

Hitti, E. A., El-Eid, G. R., Tamim, H., Saleh, R., Saliba, M., & Naffaa, L. (2017). Improving Emergency Department radiology transportation time: a successful implementation of lean methodology. BMC health services research, 17(1), 625. DOI: 10.1186/s12913-017-2488-5

Huang, H. K. (2011). PACS and imaging informatics: basic principles and applications. John Wiley & Sons.

Huang, H. K. (2019). PACS-based Multimedia Imaging Informatics: Basic Principles and Applications. John Wiley & Sons.

Ienca, M., Ferretti, A., Hurst, S., Puhan, M., Lovis, C., & Vayena, E. (2018). Considerations for ethics review of big data health research: A scoping review. PloS one, 13(10), e0204937. DOI: 10.1371/journal.pone.0204937

Jeyakumar, V., & Kanagaraj, B. (2019). A Medical Image Retrieval System in PACS Environment for Clinical Decision Making. In Intelligent Data Analysis for Biomedical Applications (pp. 121-146). Academic Press. DOI:10.1016/B978-0-12-815553-0.00006-9

Johnson, F. R., Lancsar, E., Marshall, D., Kilambi, V., Mühlbacher, A., Regier, D. A., ... & Bridges, J. F. (2013). Constructing experimental designs for discrete-choice experiments: report of the ISPOR conjoint analysis experimental design good research practices task force. Value in Health, 16(1), 3-13. DOI: 10.1016/j.jval.2012.08.2223

Kessler, R., Stowell, J. R., Vogel, J. A., Liao, M. M., & Kendall, J. L. (2016). Effect of interventional program on the utilization of PACS in point-of-care ultrasound. Journal of digital imaging, 29(6), 701-705. DOI: 10.1007/s10278-016-9893-x

Khajouei, R., Jahromi, M. E., & Ameri, A. (2019). Challenges of Implementing Picture Archiving and Communication System in Multiple Hospitals: Perspectives of Involved Staff and Users. Journal of medical systems, 43(7), 182. DOI: 10.1007/s10916-019-1319-0

Kohli, M., Dreyer, K. J., & Geis, J. R. (2015). Rethinking radiology informatics. American Journal of roentgenology, 204(4), 716-720. Retrieved from https://www.ajronline.org/doi/full/10.2214/AJR.14.13840

Kontopantelis, E., Doran, T., Springate, D. A., Buchan, I., & Reeves, D. (2015). Regression based quasi-experimental approach when randomisation is not an option: interrupted time series analysis. bmj, 350, h2750. DOI: 10.1136/bmj.h2750

Kovacs, M. D., Cho, M. Y., Burchett, P. F., & Trambert, M. (2019). Benefits of integrated RIS/PACS/Reporting due to automatic population of templated reports. Current problems in diagnostic radiology, 48(1), 37-39. DOI: 10.1067/j.cpradiol.2017.12.002

Larson- Hall, J., & Plonsky, L. (2015). Reporting and interpreting quantitative research findings: What gets reported and recommendations for the field. Language Learning, 65(S1), 127-159. DOI: 10.1111/lang.12115

Lazar, V. R. (2019). Evaluation of Turnaround Time (TAT) and Waiting Time (WT) For General Radiological Investigations in Our Hospital. Paripex-Indian Journal of Research, 8(6). Retrieved from http://worldwidejournals.co.in/index.php/pijr/article/view/563/562

Liao, A., & Seeram, E. (2019). Enterprise Imaging: The Next Frontier in Healthcare Technology–A Literature Review. Radiology: Open Journal, 3(1), 4-11. DOI: 10.17140/ROJ-3-119

Loewen, S., & Gonulal, T. (2015). Exploratory factor analysis and principal components analysis. In Advancing quantitative methods in second language research (pp. 182-212). Routledge.

Machin, D., Campbell, M. J., Tan, S. B., & Tan, S. H. (2018). Sample Sizes for Clinical, Laboratory and Epidemiology Studies. Wiley-Blackwell.

Martínez-Mesa, J., González-Chica, D. A., Bastos, J. L., Bonamigo, R. R., & Duquia, R. P. (2014). Sample size: how many participants do I need in my research? Anais brasileiros de dermatologia, 89(4), 609-615. DOI: 10.1590/abd1806-4841.20143705

McDonald, R. J., Schwartz, K. M., Eckel, L. J., Diehn, F. E., Hunt, C. H., Bartholmai, B. J., ... & Kallmes, D. F. (2015). The effects of changes in utilization and technological advancements of cross-sectional imaging on radiologist workload. Academic radiology, 22(9), 1191-1198. DOI: 10.1016/j.acra.2015.05.007

Mendel, J. B., & Schweitzer, A. L. (2015). PACS for the developing world. Journal of Global Radiology, 1(2), 5. Retrieved from https://escholarship.umassmed.edu/cgi/viewcontent.cgi?referer=https://scholar.google.com/&httpsredir=1&article=1012&context=jgr

Mongan, J., & Avrin, D. (2018). Impact of PACS-EMR integration on radiologist usage of the EMR. Journal of digital imaging, 31(5), 611-614. DOI: 10.1007/s10278-018-0077-8

Moodley, I., & Moodley, S. (2015). A comparative cost analysis of picture archiving and communications systems (PACS) versus conventional radiology in the private sector. SA Journal of Radiology, 19(1). DOI: 10.1016/j.imu.2018.05.001

Myers, J. L., Well, A. D., & Lorch Jr, R. F. (2013). Research design and statistical analysis. Routledge.

Nardi, P. M. (2018). Doing survey research: A guide to quantitative methods. Routledge.

Nie, D., Trullo, R., Lian, J., Petitjean, C., Ruan, S., Wang, Q., & Shen, D. (2017, September). Medical image synthesis with context-aware generative adversarial networks. In International Conference on Medical Image

Computing and Computer-Assisted Intervention (pp. 417-425). Springer, Cham. DOI: 10.1007/978-3-319-66179-7_48

Nitrosi, A., Bertolini, M., Sghedoni, R., Notari, P., Pattacini, P., Corazza, A., & Iori, M. (2015). RIS-PACS, patient safety, and clinical risk management. La radiologia medica, 120(6), 498-503. DOI: 10.1007/s11547-014-0483-z

Olthof, A. W., & van Ooijen, P. M. (2016). Implementation and validation of PACS integrated peer review for discrepancy recording of radiology reporting. Journal of medical systems, 40(9), 193. DOI: 10.1007/s10916-016-0555-9

Parikh, A., & Mehta, N. (2015, March). PACS: next generation. In Medical Imaging 2015: PACS and Imaging Informatics: Next Generation and Innovations (Vol. 9418, p. 94180G). International Society for Optics and Photonics. DOI: 10.1117/12.2081987

Patten, M. L., & Newhart, M. (2017). Understanding research methods: An overview of the essentials. Routledge.

Peck, A. (2017). Clark's Essential PACS, RIS and Imaging Informatics. CRC Press.

Pham, R., Forsberg, D., & Plecha, D. (2017). Improved screening mammogram workflow by maximizing PACS streamlining capabilities in an academic breast center. Journal of digital imaging, 30(2), 133-140. DOI: 10.1007/s10278-016-9909-6

Prevedello, L. M., Ledbetter, S., Farkas, C., & Khorasani, R. (2014). Implementation of speech recognition in a community-based radiology practice: effect on report turnaround times. Journal of the American College of Radiology, 11(4), 402-406. DOI: 10.1016/j.jacr.2013.07.008

Rachh, P., Levey, A. O., Lemmon, A., Marinescu, A., Auffermann, W. F., Haycook, D., & Berkowitz, E. A. (2018). Reducing STAT portable chest radiograph turnaround times: a pilot study. Current problems in diagnostic radiology, 47(3), 156-160. DOI: 10.1067/j.cpradiol.2017.05.012

Rathnayake, S., Nautsch, F., Goodman, T. R., Forman, H. P., & Gunabushanam, G. (2017). Effect of radiology study flow on report turnaround time. American Journal of Roentgenology, 209(6), 1308-1311. Retrieved from https://www.ajronline.org/doi/full/10.2214/AJR.17.18282

Rosenkrantz, A. B., Bonavita, J. A., Foran, M. P., Matza, B. W., & McMenamy, J. M. (2014). Is there an association between radiologist turnaround time of emergency department abdominal CT studies and radiologic report quality? Emergency radiology, 21(1), 5-10. DOI: 10.1007/s10140-013-1164-2

Saks, M., & Allsop, J. (Eds.). (2012). Researching health: Qualitative, quantitative and mixed methods. Sage.

Sarbaz, M., Hosseini, N., & Kimiafar, K. (2019, April). Views of Users Towards the Quality of Picture Archiving and Communication System (PACS) in a Developing Country. In EFMI-STC (pp. 100-104).

Schooley, B., Hikmet, N., & Atilgan, E. (2016, December). Health IT Maturity and Hospital Quality: Effects of PACS Automation and Integration Levels on US Hospital Performance. In 2016 International Conference on Computational Science and Computational Intelligence (CSCI) (pp. 45-50). IEEE. DOI: 10.1109/CSCI.2016.0016

Seeram, E. (2019). Medical Imaging Informatics: An Overview. In Digital Radiography (pp. 165-183). Springer, Singapore. DOI: 10.1007/978-981-13-3244-9_10

Stern, C., Boehm, T., Seifert, B., & Kawel-Boehm, N. (2018, July). Subspecialized radiological reporting expedites turnaround time of radiology reports and increases productivity. In RöFo-Fortschritte auf dem Gebiet der Röntgenstrahlen und der bildgebenden Verfahren (Vol. 190, No. 07, pp. 623-629). © Georg Thieme Verlag KG. DOI: 10.1055/s-0044-100728

Stoica, I. C., Mogos, S., Draghici, A., & Cergan, R. (2017). The medical and medicolegal use of the radiological image storage PACS for an orthopedic hospital. Rom J Leg Med, 25, 235-238. DOI: 10.4323/rjlm.2017.235

Suresh, K. P., & Chandrashekara, S. (2012). Sample size estimation and power analysis for clinical research studies. Journal of human reproductive sciences, 5(1), 7. DOI: 10.4103/0974-1208.97779

Tabatabaei, M. S., Langarizadeh, M., & Tavakol, K. (2017). An Evaluation Protocol for Picture Archiving and Communication System: a Systematic Review. Acta Informatica Medica, 25(4), 250. DOI: 10.5455/aim.2017.25.250-253

Tesoriero, J. A., Eddy, P., & Hasso, A. N. (2015). PACS used while on-call: a national survey of radiology program directors and chief residents. Journal of digital imaging, 28(2), 205-212. DOI: 10.1007/s10278-014-9741-9

Thyer, B. A. (2012). Quasi-experimental research designs. Oxford University Press.

Valente, F., Silva, L. A. B., Godinho, T. M., & Costa, C. (2016). Anatomy of an extensible open source PACS. Journal of digital imaging, 29(3), 284-296. DOI: 10.1007/s10278-015-9834-0

van Ooijen, P. M., Aryanto, K. Y., Broekema, A., & Horii, S. (2015). DICOM data migration for PACS transition: procedure and pitfalls. International journal of computer assisted radiology and surgery, 10(7), 1055-1064. DOI: 10.1007/s11548-014-1123-8

Waite, S., Scott, J. M., Drexler, I., Martino, J., Legasto, A., Gale, B., & Kolla, S. (2018). Communication errors in radiology–Pitfalls and how to avoid them. Clinical imaging, 51, 266-272. DOI: 10.1016/j.clinimag.2018.05.025

Wallach, J. D., Gonsalves, G. S., & Ross, J. S. (2018). Research, regulatory, and clinical decision-making: the importance of scientific integrity. Journal of clinical epidemiology, 93, 88-93. DOI: 10.1016/j.jclinepi.2017.08.021

White, H., & Sabarwal, S. (2014). Quasi-experimental design and methods. Methodological Briefs: Impact Evaluation, 8, 1-16.

Wildman-Tobriner, B., Thorpe, M. P., Said, N., Ehieli, W. L., Roth, C. J., & Jaffe, T. A. (2019). Moving Radiology Workflow to the Electronic Health Record: Quantitative and Qualitative Experience from a Large Academic Medical Center. Academic radiology. DOI: 10.1016/j.acra.2019.02.006

Yandell, B. (2017). Practical data analysis for designed experiments. Routledge.

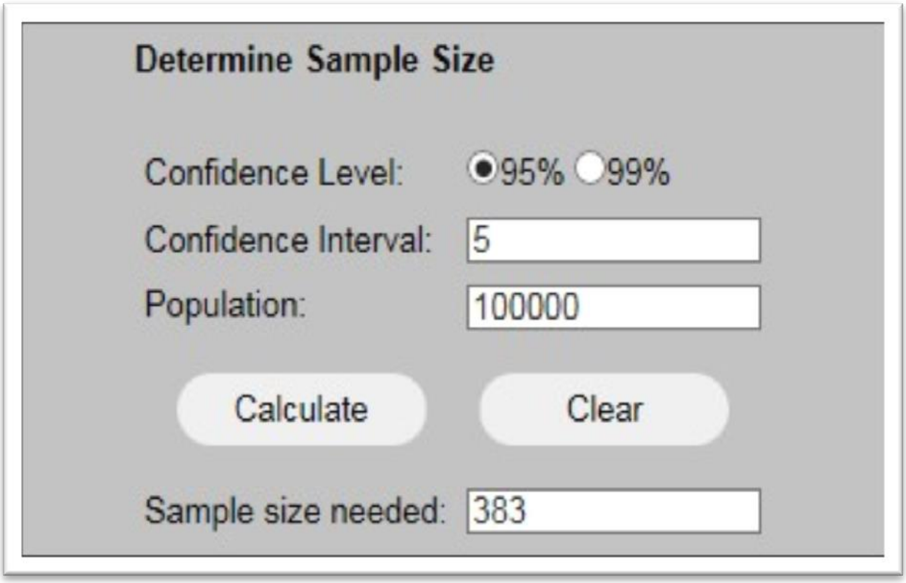
Yepes-Calderon, F., Bluml, S., Erberich, S., Nelson, M. D., & McComb, J. G. (2019). Improving the picture archiving and communication system: towards one-click clinical quantifying applications. Computer Methods in Biomechanics and Biomedical Engineering: Imaging & Visualization, 7(2), 154-161. DOI: 10.1080/21681163.2018.1466199

Zahiri, M., Farokhzadian, J., Bahaadinbeigy, K., & Khajouei, R. (2019). Factors influencing the selection of a picture archiving and communication system: A qualitative study. The International journal of health planning and management. 1-14. DOI:10.1002/hpm.2736

Zaman, M., Sajjad, Z., & Fatima, N. (2016). PACS: Taking Radiology into the 21st Century. Pakistan Journal of Radiology, 21(1). Retrieved from http://www.pakjr.com/ojs/index.php/PJR/article/view/497/513

Appendix

I. Power calculator sample



II. Ministry of Saudi Health Approval

Kingdom of Saudi Arabia
Ministry of Health
General Directorate for Research and Studies
(GDRS)

Preliminary Approval Letter **Date: 06/05/2019**

To whom it may concern

Swansea University
Health Sciences college
UK

Subject: To facilitate the mission of Mr. Mansour H. Alyami
Academic No.: A1650

Dear Sir/Madam,

This is to inform you that, this is a preliminary approval letter to ***Mr. Mansour Hussain Alyami*** who submitted an application to The General Directorate for Researches and Studies, Ministry of Health, Kingdom of Saudi Arabia (***GDRS-MoH***) to collect data for his research project titled "***Picture Archiving and Communication System (PACS) evaluation in King Khalid Hospital radiology department*** " as a part of his Master degree thesis at King Khalid Hospital-Najran, KSA to be started from **(01/06/2019)** till **(31/07/2019)** for two months.

Please note that according to our rules and regulations, the proposal needs to be reviewed and approved by MoH scientific and ethical reviewing committees prior conducting the study at MoH facilities.

Yours Faithfully,,,,,

Director General
General Directorate for Research and Studies

6/5/2019
Athari F. Alotaibi

المملكة العربية السعودية
وزارة الصحة
الإدارة العامة للبحوث والدراسات
الشؤون الإدارية و المالية

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