



IMPLEMENTATION AND INTEGRATION OF PICTURE ARCHIVING AND COMMUNICATION SYSTEMS (PACS) AT TERTIARY CARE HOSPITALS IN INDIA.

Hospital Administration

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ABSTRACT

BACKGROUND: A Picture Archiving and Communication System (PACS) infrastructure is a framework which helps to integrate various imaging systems thereby establishing a mechanism for communicating the results to the physician in a better way.

METHODS: A comprehensive descriptive and observational study was undertaken from May 2013 to July 2013. The study setting involved two tertiary care public hospitals. Purposive sampling was used to select Key Informants. The Key Informants included the Medical Superintendent's of both the hospitals managed by same top management, Head of the Radio-diagnosis department, PACS engineer, Senior Technician and Head of IT department.

RESULTS: The workflow in the department had shown various changes before and after the conduct of a particular examination. However, the examination phase remains unchanged. The noticeable change was seen in the post examination phase between the completion of the procedure and availability of images to the radiologists and clinicians. Before PACS implementation, the examination was followed by approximately an hour long process of film development which was further followed by the sorting of the previous images before the patient folder could reach the radiologist. Post PACS this had been replaced by a five minute activity of processing a plate, containing a cassette with patient details, and the screen containing image, in the CR processor and transmitting the image to PACS by a technician.

CONCLUSION: In order to have an effective PACS system in function, it is very important to have a need analysis regarding the same stating the requirement and the expected benefits to be achieved. Before planning for implementation, the team should be formulated comprising of all the stakeholders like the Medical Superintendent, Administrators, Radiologists and Clinicians.

KEYWORDS

PACS, RIS, HIS, Radiology

Background:

A Picture Archiving and Communication System (PACS) infrastructure is a framework which helps to integrate various imaging systems, providing database management of entire radiology-related information, helps efficient viewing of images, analyzing and storing study results and thereby establishing a mechanism for communicating the results to the physicians in a better way (Huang & Taira, 1992). The installation of PACS is the 'logical consequence' of the introduction of information technologies in many different fields in medicine. It is one of those important steps on the way to a digitized hospital. (Ralston, Coleman, Beaulieu, Scrutfield, & Perkins, 2004)

The planning and purchase of PACS is a major financial investment and its implementation has a long-term effect on a provider's daily operations. (Mancino & Russo, 2007) The evaluation of PACS implementation has been done from various perspectives. (Buccoliero, Calciolari, Marsilio, & Mattavelli, 2009) The impact of PACS on the overall efficiency of delivering imaging services has been calculated to reduce the cost per image produced in the face of increasing demand for the service. (Sutton, 2007) Various studies have also stated that user acceptance is an essential tool before implementing PACS as it greatly determines the success rate. (Aldosari, 2012)

METHODS

A comprehensive descriptive and observational study was undertaken from May 2013 to July 2013. The study setting involved two tertiary care public hospitals (main hospital and an associated hospital) located at different and distant locations in the same city with different technicians while the patients and end users were shared for both the hospitals. Both the hospitals were under the same top management control with disaster data recovery available at both the places. For Understanding the comprehensive planning, the process of PACS implementation and integration, Purposive sampling was used to select Key Informants. The Key Informants included the Medical Superintendents' of both the hospitals managed by same top management, Head of the Radio-diagnosis department, PACS engineer, Senior Technician and Head of IT department. 24 respondents were selected from these hospitals. Among them were Radiologists (6), Clinicians (5), Technicians (6), IT Support Team (4), Medical Superintendent (2) & GE PACS Engineer (1). Non-participant observation was done to analyze the workflow of the radio diagnosis department of the hospital. Semi-structured interviews were conducted with the Key Informants to understand the comprehensive

planning for implementing PACS along with the process of implementation, PACS workflow and the changes in the workflow in the radiology department.

RESULTS

On interviewing the Medical Superintendents, various parameters were noticed that are important while planning, *Need Analysis* being the most important one. The administration felt that before planning for PACS implementation, it was very essential to list the expectations of each user department from the new software and their specific requirements towards reports and alarms required. In case of existing software, as RIS and HIS already existed in the hospital, it was essential to list down the features in the existing software and the features which were desired after implementation of PACS. The joint proposal was made by the Medical Administration, Radiologists along with end users and the top management allocated the budget for the implementation and integration of PACS at these hospitals.

Once the proposal got approved, *Prospective Vendors were consulted*, followed by analyzing the credentials of the organization and the product details with the exact features available. Based on the hospital's requirement from the user departments, few products were selected. During this process, each user department first confirmed whether departments's requirements were met or not. Most of the expectations were fulfilled by matching their lists with features and functionalities of various products under consideration.

Considering budget and other requirements, vendor selection was completed which was further followed by *Team Building*, responsible right from the selection process till the successful implementation. Specific responsibility of each team member was also documented. The most important tool for a perfect teamwork was *Communication Process*. Lack of communication or inadequacy in communication could lead to failure both in selection or implementation, and as a part of communication plan, the channel to resolve the issues were identified.

Administration also felt that training was an integral component towards the success of the implementation plan. The plan was put in place for the pre and post installation training in the hospital.

PACS Implementation Process

PACS implementation at the main hospital started in the year 2003. General Electric (GE) was the PACS provider and the initial hardware

and software required for it was installed in 2003 itself. All the radiology equipment were DICOM (Digital Imaging and Communications in Medicine) compatible at the time of installation. Along with that the hospital also had a fully functional Hospital Information System (HIS) and Radiology Information System (RIS) in 2003 and the radiology department was a blend of Computed Radiology (CR) and Digital Radiology (DR). The PACS at the associated hospital, under the same top management was installed in the year 2012 and a part of it was still underway. At this setting, all the equipment were not DICOM compatible and had a Computed Radiology system which was planned to be transformed to Digital Radiology in due course of time.

Radiology Information System at both the hospitals was provided by Electronic Corporation of India Ltd. (ECIL). PACS Centricity 2.0 was introduced after that and its integration with the existing RIS was performed by the collaboration of Wipro GE, ECIL and the Computer department of the Hospital. The PACS Centricity 2.0 was replaced by PACS 3.0.2 in 2011. The software was updated because the hardware and the software had become outdated along with change in user requirements. The storage capacity was also reinforced to take care of increasing patient load at the hospital. The system was more advanced in the technology with a robust disaster backup.

Once PACS was installed and further upgraded, another task during implementation was to integrate various modalities with PACS. The main hospital had all the equipment which were DICOM compatible while all the equipment were not DICOM compatible at the associated hospital as most of the equipment had not completed their operational life so could not be replaced. At the main hospital, all the images were made available on the PACS network and clinicians and radiologists were advised to use digital images on their workstations for the purpose of reporting and diagnosis.

The next step was to introduce the speech recognition software at the radiologist's reporting stations. The speech recognition technology was attached to all reporting workstations at the main hospital while the case was not the same at the associated hospital where the speech recognition facility was not available.

The PACS 3.0.2 had an online temporary storage capacity of 8 Terabytes (TB). The duration of online storage was 2 years after which the images were automatically archived in the long-term storage device. A DICOM acquisition server (DAS) was used to compress the images for storage and the decompression for the viewing. From the online temporary storage the images were transferred to the permanent storage archive which was used to store the entire data which had an unlimited capacity and could also be expanded by adding terabytes. The images stored in the short term and permanent storage were connected to and available at the radiologists workstations across different departments of the hospital via a hospital wide Local area network and the images were transferred to two different settings with the help of internet dedicated leased line provided by BSNL and the images could be viewed at the other hospital at distance.

PACS Pathway

During registration, patient details were entered into the Hospital Information System (HIS). A requisition was provided stating the requirement of the radiological examination for the patient. When the patient arrived at the radiology reception, Radiology Information System (RIS), displayed the demographic details of the patient, extracted from the HIS. The type of examination to be done was selected from the list. HL7 was the format in which clinical information was accepted by PACS. Therefore, the patient information along with examination details created a requisition which was converted into a Health Level 7 message by a bridge and transmitted via broker to the PACS server. The Health Level 7 server was responsible for receiving the data from the HIS/RIS and populating this data into PACS database. HL7 was the interface standard for data transfer between hospital information systems. Integrating HIS/RIS with PACS had got certain advantages like there was a single point of entry for data which avoided duplication and access to scheduling information also helped in managing image storage.

Further, a memo was created which indicated the amount payable for the respective examination to be done for the patient. Once this amount was paid an appointment was created in the Radiology Information System (RIS) containing the patient details, the examination to be

done, the region involved and the date of the procedure. HL7 server again transmitted the appointment to the Modality Work list Server (MWL Server). This message was also sent to PACS server so that prefetching of the previous image could be done and they could be brought into the online storage. The MWL server received various requests from the clinicians thereby generating a list of examinations to be carried out by various modalities called a *Modality Work List*. Based on this work list, the examinations were carried out on a day to day basis.

The images generated from various modalities (DICOM compatible) passed through the DICOM acquisition server (DAS) where the images were compressed in size. There were three DAS at the main hospital and two at the associated hospital. Once the image was received from the modality, F5 decided the availability in one of these DAS and identified the free DAS thereby helping in balancing the load of DAS. DAS had storage of 12 Terabytes.

The DAS further sent the images to the main PACS server and the images were stored in the online storage. These images became available for viewing by the radiologists and the clinicians simultaneously at their respective workstations. At the associated hospital where the modalities were not DICOM compatible, the images were sent to the acquisition computers which converted the images into the format accepted by PACS.

Enterprise Archive was a window based system, where the data was stored for a few days, transferred from DAS. Enterprise Archive had got a water level designed and defined, once that level was reached the Database replication server took away the entire data from the short term memory and transferred it to the long term memory and data was removed from the short term memory and Enterprise Archive.

In the earlier version of PACS, the data was transferred from DAS to MOD which was the long term memory. MOD was a double sided DVD.

When a radiologist selected an image to be viewed, it was directly retrieved from the online storage after being decompressed by the DAS for the purpose of viewing. However, when the clinician selected an image for viewing, it was retrieved from the online storage by the web server which made the image available at the clinician's workstation through the LAN. Based on these images, the reports were written by the radiologists on paper which were further typed into the RIS. The typed reports were further sent to the radiologists for authorization following which it was sent to the PACS server after conversion into an HL7 message by HL7 server and these reports were integrated with the images of patient examinations and made available on LAN for the clinician access.

RIS was connected to PACS server and actively sent information about requisition, appointment and report. As this information was updated on the PACS at each stage, the status of the examination as displayed by PACS to the users also changed from time to time. The user portal contained following heads in order to access the relevant information:
Ordered - Examination conducted but images not yet available on PACS.

Arrived - Images available on PACS.

Verified - Images for radiologists and no more images will arrive.

Transcribed - Preliminary report has been typed.

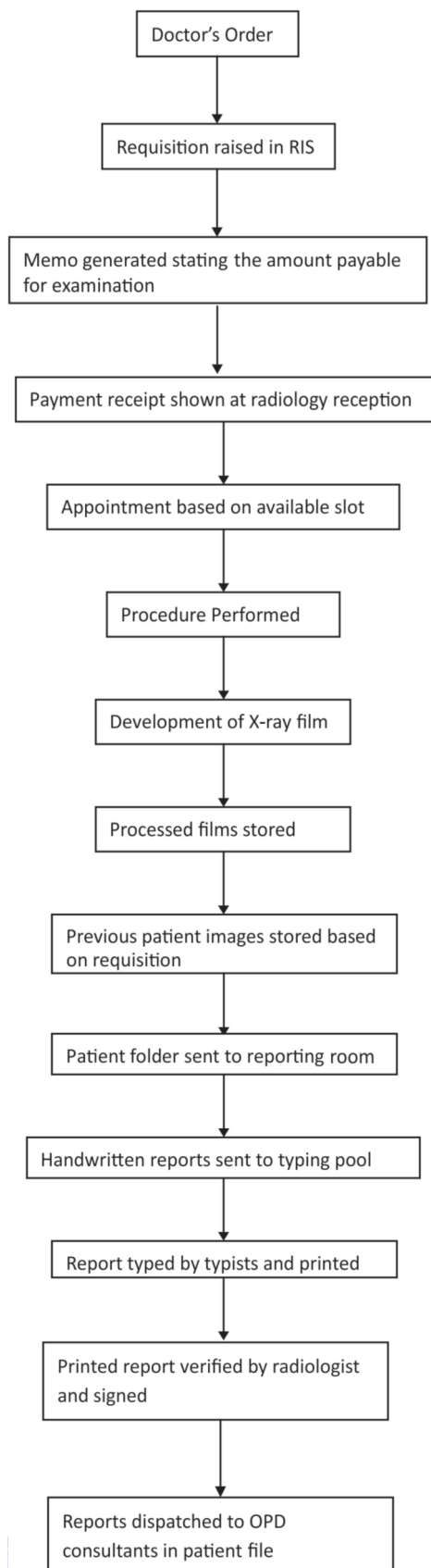
Completed - Preliminary report authorized and final report available on PACS.

Retrieval of older images by a clinician could be a pre-fetch or an ad-hoc fetch. Pre-fetching was the transfer of previous images from the permanent storage to the temporary storage triggered by an appointment given to the patient on a particular date as the images were stored in the temporary storage for about 2 days and took a minimum of 5 minutes. However, an ad-hoc fetch referred to request for older images by a clinician not as a part of requirement for the current procedure. In this images were retrieved from the permanent storage which took greater amount of time and required the manual insertion of DVD's in device in response to an image request. The amount of load on PACS also depended on the number of people who were logged in at any given point of time.

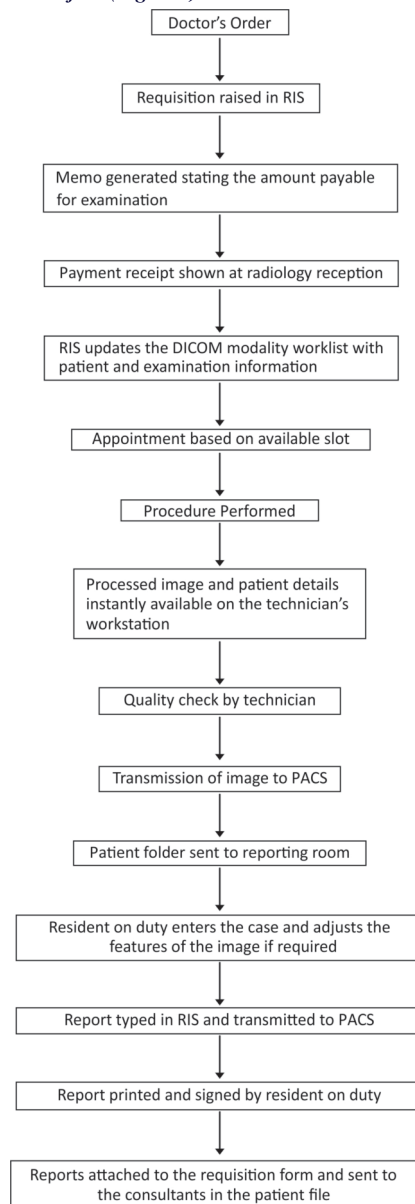
For proper integrated workflow, avoiding duplication of data entry,

both the RIS and PACS needed to be able to use DICOM for communication within the radiology department and HL7 for external communications. The Radiology Workflows Pre-PACS (Figure 1) & Post-PACS (Figure 2) are given below:

Pre-PACS Workflow (Figure 1)



Post-PACS Workflow (Figure 2)



The workflow in the department had shown various changes before and after the conduct of a particular examination. However, the examination phase remains unchanged. The noticeable change was seen in the post examination phase between the completion of the procedure and availability of images to the radiologists and clinicians. Before PACS implementation the examination was followed by approximately an hour long process of film development which was further followed by the sorting of the previous images before the patient folder could reach the radiologist. Post PACS this had been replaced by a five minute activity of processing a plate, containing a cassette with patient details, and the screen containing image, in the CR processor and transmitting the image to PACS by a technician.

PACS implementation made the entire process efficient and smooth and the entire process can be summarized into four simple steps –

1. Patient Registered
2. Examination Performed
3. Radiologist read, dictate and approve
4. Referring physician accesses report and films

DISCUSSION

PACS these days has become an integral part of the radiology department of a hospital. However, the technology continues to evolve and improve at the same time, the key practical issues and challenges still remains which need to be addressed. (Berkowitz, Wei, & Halabi, 2018)

There are multiple issues in implementation of PACS. Vendors try avoiding or negotiating on the various specifications as required by the hospital. Once agreed on that, they fail in terms of providing software up gradation and enhancements. There has always been a tug of war between vendor and the hospital acquiring the software in terms of the specifications required. (Kalyanpur, Singh, & Bedi, 2010)

It is essential to integrate HIS/RIS to PACS so that it combines patient's data with the respective image and the entire set of data with image makes considerable sense to the end user collectively. HL7 acts as an interface between HIS/RIS and PACS so that PACS broker contains details regarding patient demographics and other data. There were certain times when HL7 server becomes inactive and the procedure was stuck. In such cases the examination gets delayed causing inconvenience to the patient. An important characteristic that has been often explored in studies is the degree of PACS integration with the radiology department's diagnostic modalities, Radiology Information System and Hospital Information System stating the minimum degree of integration guaranteed between PACS and HIS consists of electronic request form. (Buccoliero et al., 2009)

There had been cases in the hospitals where the PACS server was down and the clinicians were not able to review any images until the server was retrieved. It led to enormous trouble to the patients and the doctors themselves. (McBiles & Chacko, 2000) Few studies report the downtime issues which were not substantiated by a very authentic and satisfactory recovery solutions. (van de Wetering & Batenburg, 2009)

To address technical issues related to troubleshooting and maintenance well trained PACS personnel along with IT support team are required and most importantly the urgency of co-ordination should be taken care of. Periodic interaction between the users and the vendor is crucial to optimize PACS utilization. The key success depends upon the understanding and the co-operation which in turn depends on the quality of interaction between the clinical staff and the IT department. However, one should not ignore the scheduled preventive maintenance for application software and the hardware.

PACS server preventive maintenance through annual maintenance contracts with the vendor is also important to ensure hardware uptime, given that hardware outages can be devastating to a network's infrastructure. (Kalyanpur et al., 2010)

At times up gradation becomes necessary in order to obtain a better infrastructure. It is always difficult to decide whether to upgrade on the same vendor or switch vendor. (Kalyanpur et al., 2010) It is recommended to have a clause in the contract regarding the same within a certain time period and in case it exceeds, up gradation should be done at a certain amount of fixed price depending on certain amount of required specifications. Switching to a new vendor due to reasons of obsolescence is not advisable. This particularly involves re-training, inviting resistance to a new application and would also need to address enormous compatibility issues.

CONCLUSION

In order to have an effective PACS system in function, it is very important to have a need analysis regarding the same stating the requirement and the expected benefits to be achieved which in turn states the utmost need of a comprehensive business plan in place. Before planning for implementation, the team should be formulated comprising of all the stakeholders like the Medical Superintendent, Administrators, Radiologists and Clinicians.

The pre-requisites should be followed in terms of DICOM compatibility, well developed Hospital Information Systems and Radiology Information Systems, etc. Once all the prerequisites are in place, then PACS implementation should be done. It is advised to decide the configuration and specifications before approaching the vendor rather than going otherwise.

The expected advantages of PACS were mainly focused to solve the problems of the film based environment in terms of film loss, timely availability of the images at the clinician's workstation, lost images, decreasing unnecessary repetition of examinations due to unavailability of previous images etc.

The most important advantage achieved and perceived was the accessibility to the images and the improved display as revealed by the

user display workstation survey. There was no more transferring of films between the departments on manual basis leading to unnecessary delays.

However, it also had a certain disadvantages basically related to lost images, unable to retrieve, downtime issues, etc. which needs to be addressed.

PACS and technology both are evolving rapidly and have certain sets of issues and challenges pre and post-implementation which need to be addressed. The key factors that determine its optimal utilization are systematic planning, appropriate vendor, phased implementation, proper coordination between the users, vendors and IT support team, periodic training, and regular maintenance and up gradation. Moreover, it should be viewed as a continuous process in which the initial solutions can be further improved with adjustments and modifications.

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