

Introduction to Picture Archive and Communication Systems

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ABSTRACT: Picture Archive and Communication Systems (PACS) are comprehensive management systems for diagnostic imaging studies that are increasingly used in hospitals and health care systems. It is essential for PACS to be an integrated part of the total hospital electronic information system in order to be maximally effective. The main objective of any new information system in health care is to improve the effectiveness and efficiency of health care. Although the initial implementation of PACS is costly, the ability for care providers to have faster access to diagnostic imaging information allows care to be delivered more expeditiously, which improves the overall quality of care patients receive. Nurses will have the ability to see images, rather than just reports about imaging studies. An electronic system for diagnostic imaging procedures and management provides nurses with unique opportunities to improve their involvement in clinical discussions, their ability to provide quality patient care, and potential to further nursing research. (*J Radiol Nurs* 2006;25:69-74.)

INTRODUCTION

Diagnostic imaging is a key component of information affecting the care a patient receives. Picture Archive and Communication Systems (PACS) are comprehensive networks of digital devices designed for acquisition, transmission, storage, display, and management of diagnostic imaging studies. The concept of a digital image communication and display system was devised in the 1970s, with the initial conference on PACS de-

signs launched in 1982 (Huang, 1999, 2003). The U.S. Army Medical Research and Materiel Command installed the first large-scale PACS in the United States called the medical diagnostic imaging support system in 1992 (Smith et al., 1995). Since that time, PACS technology has grown through the support of InfoRAD displays during the Radiological Society of North America (RSNA) annual meetings and other conferences, as well as the establishment of a peer-reviewed journal, the *Journal of Digital Imaging*, devoted to research in digital technology. In the past few years, PACS have become widely used by hospitals (Liu et al., 2004). The initial deployment of comprehensive PACS was hampered by a wide host of issues related not only to its high start-up cost but also to the acclimation of the technology for routine clinical use (Huang, 2003). The transition from conventional “hard copy” films to “soft copy” interpretation on computer monitors has been tedious, but the technology and acceptance of digital imaging systems are growing. Aside from the determination of the minimum image quality requirements for accurate diagnosis assurance, a whole host of end-user issues had to be overcome such as the optimization of computer interfaces, image archival speeds, viewer settings, algorithms for data display, and appropriate ergonomic environment for both image acquisition and image viewing. In addition, the integration of routines common for “hard copy” radiology departments, such as the ability to fetch old exams and old reports as well as annotate

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images (traditionally performed with a nonpermanent wax pencil), had to be replicated in the virtual digital PACS environment.

Like other electronic hospital information systems, PACS are expensive to install and, thus, it can be difficult initially for health care facilities to justify its cost, especially for small facilities. In PACS, cost is particularly high because of the size of individual imaging exams that can often strain the limits of data archival storage, transmission, and viewer display as image data sets are often large (e.g., 36.7 MB per CT study or 16.7 MB per two-view conventional x-ray study; Mehta, Dreyer, & Thrall, 1999). Despite the high cost of PACS and other electronic hospital information systems, hospitals are discovering the cost effectiveness of these systems in the delivery of health care (Huang, 1999). PACS are now being considered an essential part of the continuity of care in the hospital environment (Liu et al., 2004). Studies have documented savings in terms of lost studies that required repeat of the exams and time required for house staff attempting to locate films. The PACS enable several people to view the same exam simultaneously at different locations, which is typically not practical with hard copy films. For many patients, x-rays are also used as a final check before discharge. In hospitals with PACS, the easy access to patients' films often leads to earlier patient discharge and shortened hospital stays (Hirschorn, Hinrichs, Gor, Shah, & Visvikis, 2001; Watkins, Weatherburn, & Bryan, 2000).

Computerized health care systems give hospitals a competitive advantage through cost savings and improved patient perception (Brink, Neklesa, Mutalik, & Forman, 1998). The potential for referring providers to access patients' films in the hospital, their offices, or clinics provides additional illustrative tools for patient discussions concerning their medical management and treatment options. Furthermore, patients perceive

hospitals that have computerized health information systems as being more modern and having more state-of-the-art care capability. Patients want to feel they are receiving the best care possible.

One of the main goals of PACS is to make the delivery of health care more effective and efficient. To date, there is little published information regarding the clinical impact of PACS in the working environment. PACS are new tools that need to be studied by nurses to see how they can improve the delivery and quality of care to the patient. This article will describe the basic structure of a Picture Archive and Communication System and how it relates to other electronic systems in the health care enterprise. In addition, the various ways in which PACS are being used in the health care settings and their effect on nurses, patients, and the delivery of care will be discussed.

DEFINITIONS

The electronic communication systems that are used in health care have a unique vocabulary that is sometimes confusing to users in the health care system. Defining these components and how they relate to the old, paper-based system is the first step in understanding how an electronic radiology department operates. Old paradigms in basic radiologic functions relating to the nurse are outlined in Table 1.

Digital imaging and communications (DICOM) systems: A standard for the facilitation of electronic medical imaging, consisting of a standardized image format and a standardized communications protocol (American College of Radiology, 2001).

Electronic health record (EHR): An electronic system that is used to capture, retrieve, store, transmit, manipulate, and link any information that relates to the past, present, and future health or conditions of any person for the primary purpose of providing health care or health-related services (Englehardt &

Table 1. Comparison of paper-based communication to electronic communication

Paper-based system	Electronic system
Hard film	Electronic image
Light-box	Computer screen
Written paper prescription	Electronic order
Film jackets	Optical media
Written reports	Electronic reports
Reports mailed or faxed	Reports e-mailed or retrieved electronically
Films collected and sent with patient to operating room	Views available in operating room to electronically recall images
Films collected and sent with patient when patient is transferred	Images retrievable through Picture Archive and Communication Systems, no need to gather old films
	If patient is transferred to another institution, images are sent with patient on a CD or DVD
	Old films electronically recalled from deep archive or electronic long-term storage in seconds or minutes
Long time to retrieve old films from file room or off-location storage. Can take up to a week	Electronic medical record
Paper patient chart	

Nelson, 2002). EHRs are usually based on the Health Level Seven (HL7) standard.

Health care information system (HIS): An integrated system of both hardware and software that is used by a health care provider to support and conduct all information aspects of providing quality patient care and the business of health care (Engelhardt & Nelson, 2002).

Radiology information system (RIS): An electronic system that is used to manage medical imaging information such as diagnostic imaging orders, scheduling, and diagnostic imaging interpretations/reports and to prepare billing information (Levine, Norton, & Mun, 1995). RIS is usually based on the HL7 standard.

Picture Archive and Communication System: A system for digital image data management. The main components of PACS include image acquisition, data management, data transmission, image display, interfaces to printers and portable media, and communication routes to other electronic systems (Chopin, Boehme, & Maynard, 1992). PACS are usually based on DICOM standards.

Health Level Seven (HL7): An electronic communication standard for health care applications that facilitates clear communication in the health care community through an agreed upon format or protocol for electronic data exchange (Dolin et al., 2001).

STRUCTURE OF PACS

PACS usually require at least a gigabit backbone of infrastructure to form the network, imaging workstations

and other complex computer stations for viewing the images and related health information, interfacing devices, immediate and short-term storage, and long-term storage databases (Erickson et al., 2001; Huang, 1999). Two main types of viewing stations are used in PACS: high-resolution 3- to 5-megapixel diagnostic workstations for formal diagnostic interpretation and lower resolution stations (e.g., 1- to 2-megapixel workstations) for easy clinical reference used throughout the rest of the PACS network outside of the interpreting department. The high-resolution 3- to 5-megapixel monitors are expensive but necessary for accurate diagnosis. These more expensive monitors are typically only purchased for the radiology department and select clinics (e.g., orthopedic clinics). Most clinics cannot justify the high cost of the 3- to 5-megapixel monitors to review films.

It is extremely important that communication with the PACS, RIS, and/or HIS be bidirectional for maximum enterprise benefit (Penn PACS Technology, 2002). Just being able to send images is not sufficient information exchange for good patient management. This lends itself to improved accuracy of information that in turn leads to increased efficiency of health care delivery. Radiology imaging networks must be capable of handling large amounts of data that are generally stored on a redundant array of inexpensive disks for short-term storage and have digital tape or other optical disk-based systems for long-term storage so that the flow of information can be rapid (Arenson, Andriole, Arvin, & Gould, 2000). Reports are available on the HIS or the RIS so that clinicians have a report when they review films on the PACS. A schematic of

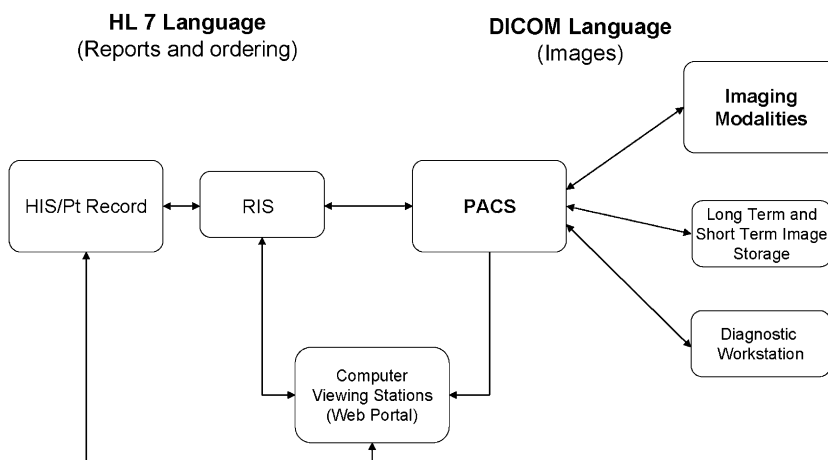


Figure 1. A simplified schematic of a Picture Archive and Communication System (PACS) and its communication flow to other basic components of the electronic health record such as the radiology information system (RIS), health care information system (HIS), and other computers used in the health care setting. Of course, good clinical practice dictates the protection of patient privacy and confidentiality; thus, the communication pathways are designed with security features such as firewalls, encryption, audit trails, and access restriction to protect patient privacy and the fidelity of the images.

the basic components of a picture archive and communication system and how it relates to the RIS and HIS is demonstrated in Figure 1.

CLINICAL IMPLEMENTATIONS

A survey conducted by Yousem and Beauchamp (2000) looked at three key issues clinicians hoped PACS would help improve upon: the length of time between ordering the exam and receiving the results, lost films, and lack of previous films for comparison. Through the alleviation of these problems, clinicians resoundingly hope to greatly improve the care to the patient. Kinnunen and Pohjonen (2001) took these key issues further by pointing out that PACS change the roles of the resources by making the data mobile instead of relying on people to move the images. Health care managers know that manpower is expensive. It makes sense to let computers organize and move data so that people such as nurses can spend more time giving care (Yu & Hilton, 2005). A report by Brink et al. (1998) found that PACS improved patient care through more timely adjustments to the patient care regimen. Outcome studies have shown a decrease in the average length of hospital stay for patients where PACS have been implemented (Brink et al.; Siegel & Reiner, 2002). The importance of an integrated health management system has been recognized by the Hospital Information Management Systems Society and the RSNA among others (Arenson et al., 2000; Boochever, 2004). Their joint initiative to facilitate HIS/RIS/PACS connectivity is called Integrating the Health Care Enterprise (IHE). The IHE task force is working to improve access to information across all health care systems by establishing common integration protocols such as HL7 and DICOM.

The other big problem with hard films is that they are often lost and may not ever be formally interpreted. Now, since diagnostic images are electronic, the computer systems aid in tracking films and reports. It is estimated that approximately 10% to 20% of hard copy films are missing or unavailable when needed (Kinnunen & Pohjonen, 2001). The loss of a prior study may result in incorrect medical management as much of radiology relies on the principle of interval disease monitoring to assess disease remission or progression. The loss of a current study would result in a repeat exam and the needless reexposure of the patient to x-rays and a delay in final diagnosis, not to mention overall health costs (Arenson et al., 2000). PACS change the lost images rate to near zero and result in an overall improvement in patient care by reducing the aforementioned concerns related to lost films (Kinnunen & Pohjonen; Ondo, 2004). The downfall to the PACS is that it does not typically track the existing hard film cases that may also be available for comparison. A

Picture Archive and Communication System archives digital studies that are put into the system. Some institutions have RISs that are capable of linking to legacy reports for studies that were performed before the PACS were installed. The old films would still need to be retrieved from the file room unless the old films have been scanned into the PACS (Dzingle, May, & Garland, 2001). Digitizing old films is expensive and time consuming, preventing most institutions from providing this feature; therefore, old films should be digitized according to clinical protocols developed by radiologists/physicians.

One of the greatest impacts of PACS on the care provider is the ability to view the images and results in the clinic much faster than the old system of going physically to the film library and checking out hard copy films and either waiting for reports to be transcribed or calling the radiology department for a stat wet-read. Some institutions allow providers to access the voice recordings of a radiologist's report before the written report that is done by the transcriptionist in order to speed up the relay of information (Arenson et al., 2000). However, having to access the report through the telephone transcription systems is time consuming and adds an extra step to the nurse's already busy schedule. One additional way reports are being generated in a more expedient manner is with the use of voice recognition systems. Some institutions are using voice recognition packages to digitalize transcriptions, thus eliminating the need for transcriptionists. However, this transition to voice recognition is slow, since some hospital personnel are still skeptical of this new technology and the technology is still being refined to meld the demands of the physician dictating the reports. Institutions that have successfully adopted voice recognition software in their dictation systems report more timely and improved access to patient reports that are readily available through electronic retrieval (Bramson & Bramson, 2005).

DISCUSSION

The American Nurses Association endorses the findings that electronic patient records reduce errors, improve the speed and efficiency of care, and benefit the overall care of the patient (Computer-based Patient Record Institute [CPRI], 1995). Most data thus far show that PACS speed the transfer of image data to the care providers and reduce the number of lost films. This is particularly evident in the emergency room and intensive care units where prolonged wait times for study results can have a fatal or at least morbid result in patient management and care (Hirschorn et al., 2001; Watkins et al., 2000).

The ultimate goal of any new implementation in health care is to improve the delivery of care. Computers offer the potential to greatly enhance the cost effectiveness of the health care system through long-term, comprehensive foundation of information (CPRI, 1995). A successfully integrated PACS/RIS/HIS in a hospital increases the functionality of the hospital system and enhances the overall quality of care to the patient (Arenson et al., 2000; Siegel & Reiner, 2002). Nurses who have access to the total health information of patients have the ability to care more efficiently and effectively for patients. A study done by the Baltimore Veterans Administration Hospital showed that clinicians tend to view the images of the exams they ordered through the PACS more frequently than they did when the images were only available on hard film (Reiner et al., 2000). PACS will become another regular tool along with the electronic patient record, medication administration record, and other electronic information devices for all health care providers.

Nurses see providing quality patient care as a vital element of their practice since they deliver the bulk of patient care. EHRs, such as medication administration records, have been found to reduce the risk of medication errors, save time in documentation, and reduce the time necessary for restocking medications on the units (Tamblyn, 2004). It has also been found that EHRs, especially when nurses use handheld devices, allow nurses to have more time for patient care delivery through improved access to information, improved communication, and specialized tools for assessing and calculating dosages or other clinical values (Tamblyn). The electronic information systems are meant to be tools to enable nurses to make better decisions and be more proficient in their clinical practice.

PACS can also be used by nurses to search for diagnostic imaging data for use in research and education. For instance, a nurse researching a project on patients with diabetes mellitus may want to review the most common life-threatening and quality-of-life-reducing pathologies associated with diabetes mellitus. The nurse researcher could search the diagnostic imaging reports in the HIS or RIS and then easily find the corresponding imaging files that demonstrate the common pathologies relating to diabetes mellitus. By inserting the images into the research reports, nurses may learn more about how these pathologies appear on diagnostic studies and may be able to better inform patients on how these chronic illnesses may affect their lives (Marshall & Evans, 1992). Images can also make research reports more visually interesting, thereby potentially increasing understanding and retention of the topic. In addition, the PACS and the RIS can serve as secondary data sets for nursing research. It may be

possible to track patient encounters or problems that could be overlooked during clinic visits through the documentation of diagnostic imaging procedures. The nurse could also use PACS to perform utilization studies or other types of health care research.

PACS images can be helpful during nursing shift change conferences or for educational forums to further demonstrate key points of certain illness or disease. A nurse may have a patient who has a pleural effusion who is undergoing serial chest x-rays, or there may be several patients with feeding tubes that may need to be periodically evaluated. The nurse could easily refer to the digital films during postconference as an additional source of information that the nurses could use for monitoring patients' tube placement or resolving pneumonia in addition to the provider's orders.

A nurse interested in investigating improvements in patient education may want to review the impact of PACS on patient education. For instance, maternal bonding has been shown to improve when the patient views obstetric ultrasound images (Fletcher & Evans, 1983). Commonly, expectant mothers are given images of their obstetric ultrasound. Similar improvements in patient education and acceptance of their condition may be gleaned by the integration of PACS into patient and family counseling sessions. For example, a nurse may want to research the impact of patient and family discussions with the inclusion of CT images of a malignancy. The images could be used to describe the seriousness and the extent of the tumor and help describe the seriousness of the surgery and its preparation. Images also could aid in the explanation of the possible postoperative consequences for the surgery such as the need for an ostomy bag or location of a drainage tube, since visual images are often easier to understand than written or verbal explanations. In addition, programs can now insert images into patient reports, which may enhance the patient's understanding of the diagnostic study. Nurses can use this new image feature in their patient education encounters to help improve patient compliance and, consequently, improve clinical outcomes.

EMERGING TECHNOLOGIES

As PACS technology evolves and is widely incorporated in the health care setting, some emerging technologies that will assist nurses in the radiology department include computer-assisted readings (CAR) or computer-aided diagnosis. Certain radiologic examinations and procedures such as digital mammography, virtual colonoscopy, and virtual angiography may be enhanced by CAR technologies that offer initial interpretations or interpretation assistance (Ford et al., 2005;

Jiang & Metz, 2006; Li, Clark, & Thomas, 2002). It is hoped that these tools will add to the information available to the nurse in helping patients plan for their health care needs.

SUMMARY

PACS is not simply filmless diagnostic imaging; it is a part of a total HIS that is essential for quality patient care. It is only a matter of time before truly digital hospitals and health care systems are the norm. PACS will play an important role in this total digital conversion in health care. PACS can benefit nurses by helping make the diagnostic decision faster so that patient care can be delivered more efficiently and effectively.

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