

KNOWLEDGE MANAGEMENT
IN HEALTH CARE

Picture Archiving Communication System (PACS)

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INF 385Q · Fall 2008

Health care may depend on knowledge management more than any other industry due to the overwhelming concern for patient welfare. Syed Abidi defines health care knowledge management as the “systematic creation, modeling, sharing, operationalization and translation of [health care] knowledge to improve the quality of patient care” (Abidi 2008). This effort to improve patient care has forced health care organizations to manage a diverse portfolio of information systems, which may have varying levels of interoperability. To add to the knowledge challenge, health care is experiencing rapid generation of new knowledge but is unable to “disseminate, translate and apply *current* [health care] knowledge in clinical practice” (Abidi). This paper will explore how a system dedicated to diagnostic imaging contributes to the health care knowledge portfolio.

The medical field uses a variety of diagnostic imaging modalities such as Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Nuclear Medicine, or X-Ray to help medical professionals assess and diagnose a variety of medical conditions such as bone fractures, cancer, or vascular disease. In the past, most of these modalities recorded output onto analog film and stored them just the same as or similar to any other paper record. As these modalities made the transition to electronic and digital output, the systems paired with each modality were often proprietary and expensive. These systems were not interoperable, did not communicate with each other, and/or encrypted their data to prevent access by other systems. To help relieve some of these challenges, an array of many university doctors and professionals began developing a system to help manage the storage, retrieval, and archiving of these images in the early '80s. This system became known as a Picture Archiving Communication System (PACS). PACS is an independent information system, separate from a hospital information system (HIS) or clinical information system (CIS) and may not be interoperable with other systems.

Roles and workflow

To illustrate the medical imaging environment, let us examine a simple example scenario and the circle of users with a stake in a diagnostic medical image:

A *patient* is admitted to the ER due to a sharp pain in the lower abdomen. The patient wants to know what is wrong and if s/he will be OK. The *doctor/physician* meets with and examines the patient, suspects a gall stone, and orders an ultrasound image of the abdominal area. The doctor wants to rule out a gall stone. The order is received by a *sonographer* and s/he performs an abdominal scan, keeping an eye out for indications of a gall stone. The sonographer performs the scan, annotates the images, attached any related worksheets or paperwork, and sends the images to PACS for a radiologist or doctor for review. The *radiologist* is responsible for reading diagnostic images and responsible for diagnosing or prognosing a disease or condition and may be working in a remote location. A radiologist needs to quickly access an image (from PACS) and read its annotations to deliver an opinion to the doctor.

The scenario involves no less than four major stakeholders. Other roles may include staff responsible for inputting the imaging order into a hospital's information system or a transcriptionist who records the doctor's report after s/he has reviewed an image.

Anatomy of PACS

In general, PACS is comprised of several elements: DICOM standards, PACS database and file server, an archive server and system, and a RIS interface system. The Digital Imaging and Communications in Medicine (DICOM) file format provides a common standard shared by most medical images and related systems. It includes both the image and medical-specific metadata scheme for patient and exam information. When an image is "sent to PACS", it is cataloged in the database and stored on the file system. To address the long-term storage and

retrieval of these images, an archive server manages stores data onto other file servers, optical media, or tape backup and keeps track of which media they can be found. To help bridge the communication of patient information, scheduling, and results, a RIS (Radiology Information Server) interface computer communicates to PACS and other client systems.

How PACS contributes to knowledge management

Abidi identifies nine “healthcare knowledge modalities”: tacit knowledge (objectivity, instinct), explicit knowledge (clinical research), clinical experiences, collaborative problem-solving (between health care workers), operational policies, educational resources, decision support rules (data-driven decision models), social knowledge (community of practice), and data-induced observations (observations and tests). Here, we will examine how PACS contributes to some of these knowledge modalities:

Tacit knowledge — while PACS itself and the images within it are not tacit, the information they hold require a great deal of tacit knowledge in their creation and interpretation. A sonographer must exercise a great deal of tacit knowledge while they operate the equipment used to capture an image. The physical characteristics of a patient that present imaging challenges, the operation of a transducer, the hand-eye coordination of operating a transducer while viewing a screen, and imaging adjustments made to enhance detail all manifest themselves within the final image. For doctors, the final image is open to their interpretation and opinion, sometimes driven by intuition or personal experience.

Explicit knowledge — in the development and publishing of explicit medical information such as journals, clinical practice guidelines, and research, images from PACS are critical in illustrating disease and conditions to others. For doctors, these may become models for

what a particular condition will look like and therefore influence their imaging expectations when they suspect the same condition affects a patient. For imaging technicians, an explicit image in a textbook or presentation may become a model to strive for when conducting an exam on a patient. This model image will present tacit knowledge challenges as every patient will be different.

Clinical experiences — interaction with PACS is an essential task for radiologists and imaging specialists to perform their job. The submission and retrieval of diagnostic images and associated paperwork are a foundation for participating in the imaging workflow and the information needs of the larger portfolio of health care information management. If “knowledge builds on an accumulation of experience” (Choo, 2005), PACS role is important to the hospital knowledge portfolio.

Collaborative problem solving discussions — whether electronically or face-to-face, PACS provides a common ground for doctors and imaging specialists to share opinions or ask questions related to a diagnostic image. Technicians can pull images from the system to show their peers and ask questions about challenges they encountered while scanning, share opinions when comparing recent scans with previous scans for changes in anatomy, exchange techniques used to acquire better images, or share thoughts on the level of risk associated with a mass found in an image.

Educational resources — this is an area where PACS contributes very directly. All stakeholders that interact with diagnostic images benefit from PACS. Doctors, radiologists, sonographers, and technicians all pull images from PACS to compare results, share findings, accompany articles for journals, share experiences, methods, or challenges, or illustrate patient outcomes. For example, a radiologist may evaluate if in

six months, is a mass on a liver the same size as before or did it grow 4mm in diameter?

The scenario can also be shared with peers to facilitate clinical experience and collaboration. For resident radiologists learning under an attending radiologist, PACS has had a significant impact in training methodologies and relationships. Like with many other digital and online transitions, face-to-face interactions (between residents and attending radiologists) have decreased significantly. This decrease is due to a number of factors including teleradiology — where radiologists work remotely, implementation of multiple radiology workstations — communication and annotation is largely performed electronically, even if the workstations are in the same room (Deitte 2006).

Social knowledge — PACS has created a specialty among IT professionals, knowledge workers, and medical professionals. You can find blogs (doctordalai.blogspot.com), conferences (Digital Healthcare Information Management Systems), associations (PACS Administrators in Radiology Certification Association), and even open source efforts (OsiriX) focused on or including PACS issues and trends.

Data-induced observations — the recorded data that accompanies medical images such as annotations, patient data, measurements, and associated worksheets offer needed metadata for doctors and radiologists to make judgments and recommendations.

Integration with other systems

Within context of the entire medical information landscape, PACS is only one of many systems that ideally communicate with each other. Other systems in a hospital environment include:

Clinical/hospital information systems (CIS/HIS) — responsible for managing general patient information, ordered procedures, billing, insurance, bed/room assignment, and administrative reporting.

Radiology information systems (RIS) — are used specifically by imaging/radiology departments in a hospital or clinic to manage patient and imaging data. This may include appointment management, patient registration, department-specific billing, document attachment, exam reports, and interfacing with PACS.

Electronic health/medical record (EHR/EMR) — the patient-centric records that represent a compilation of medical information collected and created within a hospital or clinic's systems, including exams, labs, procedures, medications, allergies, diagnosis, and other reports.

Integration of these systems is particularly important to radiologists — typically responsible for professionally interpreting pathology in a diagnostic image. A patient's demographics, medical history, and medications can all contribute to the opinion given by a radiologist. Is it a poorly imaged kidney stone or insignificant bright spot? If well integrated, medical students can follow a patient's record from intake through outtake — observing symptoms the patient presents with, the exams ordered, the procedures performed, and medications or therapy prescribed. This integration “between diverse medical database systems such as HIS, RIS, and PACS is [...] critical to the successful management of research and teaching in radiology” (Huang 2004).

Conclusion

Health care is charged with creating and maintaining a large amount of patient information across many systems in an effort to ultimately provide better patient care. PACS is

just one of many health care information systems that contribute to the larger body of knowledge used by hospital administrators to compile statistics and reports, health care workers to inform decisions and facilitate education, and patients to understand their condition. PACS is particularly interesting as a knowledge system because it is so information-rich: images are annotated, radiologist reports are transcribed, and reports are attached. Essentially, the PACS workflow represents a continual effort to transfer explicit knowledge — each person involved is using their knowledge to create and contribute to an exam. This enables each health care worker the opportunity get a more comprehensive view of a patient's treatment and results by allowing users to ability to compare past exams with present exams — illustrating the presence or absence of pathology and prevents duplicate or unnecessary exams. For health care workers looking for example exams to study, PACS behaves as a library of exams and recorded knowledge.

However, it is important to recognize the knowledge transfer opportunity offered by PACS or any other information system is limited by the individual and organizational culture's value placed on information and knowledge sharing. Gaps in contributed information can have a domino effect down the workflow line. An overlooked exam or procedure can lead to redundancy or missed pathology, increasing time and costs for everyone involved.

Though PACS is only one component in the portfolio of health information systems available to health care organizations, it is both information and knowledge rich as a resource for informing better patient care and as a resource for study.

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