Chapter 9
PACS and Other Image Management Systems

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9.1 Introduction: What Is PACS?

DEFINITION 9.1: PACS

Picture Archiving and Communications Systems store, distribute, and display digital medical images.

Picture Archiving and Communications System (PACS) is the core technological infrastructure for enabling the management of digital medical imaging. The primary functions of a PACS are storage, distribution, and display of images. PACS functionality is further strengthened when integrated with other clinical application infrastructure, such as the hospital information system (HIS), the electronic medical record (EMR) or electronic health record (EHR), the

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B. F. Branstetter IV (ed.), *Practical Imaging Informatics*,
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radiology information system (RIS), and dictation or voice recognition (VR) report generation systems.

KEY CONCEPT 9.2: CIIP

A Certified Imaging Informatics Professional (CIIP) earns and maintains a nationally recognized credential demonstrating a commitment to and understanding of clinical healthcare and information technology in the field of imaging informatics. The American Board of Imaging Informatics (ABII) is the credentialing organization for the IIP certification and was founded in 2007 as a collaborative effort between the Society for Imaging Informatics in Medicine (SIIM) and the American Registry of Radiologic Technologists (ARRT).

Management of PACS is complex and requires skilled personnel both for the initial deployment and for ongoing system and application support. Ensuring that PACS is administered by qualified imaging informatics professionals is imperative to the overall success of a PACS program.

FURTHER READING: Return on Investment

Chan L, Trambert M, Kywi A, Hartzman S. PACS in private practice-effect on profits and productivity. J Digit Imaging. 2002;15 Suppl 1:131–6.

A new or replacement PACS implementation typically involves a combination of expenses for system hardware, software, and services. This is fundamentally different from traditional large imaging department purchases, like a CT or MRI scanner, in that PACS is not regarded as a revenue generator. It can be a challenge to quantify; however, the real value of a modern PACS comes in the improvements to diagnostic capabilities and operational efficiencies. Given the volume of medical imaging examinations and the number of images generated per study, it is difficult to imagine operating a modern radiology department without a PACS.

9.2 History of PACS

- The initial concept of PACS can be traced back to Dr. Richard Steckel in 1972.
- The first large-scale PACS was implemented at the University of Kansas in 1982.
- First-generation PACS adopters encountered many challenges with the review and archival of imaging studies across disparate platforms due to proprietary formats:
  - This gave rise to a concerted effort to create an interoperability standard.
  - In the early 1980s, the American College of Radiology (ACR) and the National Electrical Manufacturers Association (NEMA) initiated work on the formation of what is now known as the DICOM (Digital Imaging and Communications in Medicine) standard.

The **DICOM Standard** has evolved to be the primary source that defines the formats for medical images that can be exchanged with the data and quality consistency necessary for clinical use.

KEY CONCEPT 9.4: DICOM

Digital Imaging and Communications in Medicine is *the* international standard to transmit, store, retrieve, print, process, and display medical imaging information (see **Chap. 12**).

9.3 Core Components of Traditional PACS Architecture

Traditional PACS architecture contains a variety of components, and each organization's environment will be different based on numerous factors. Figure 9.1 depicts one example.

9.3.1 Acquisition Devices

- **Modalities** are the machines that acquire patient imaging, such as an MRI, CT, or US scanner.
- **Specialized workstations** are image post-processing systems that are generally a component of a modality like a CT scanner, but can also refer to standalone computers that deliver access to third-party software for advanced image processing.

DEFINITION: Modality

The word "modality" may refer to a technology used to create images (e.g., CT) or to a specific machine that is producing images (e.g., CT scanner #3 in the emergency department).

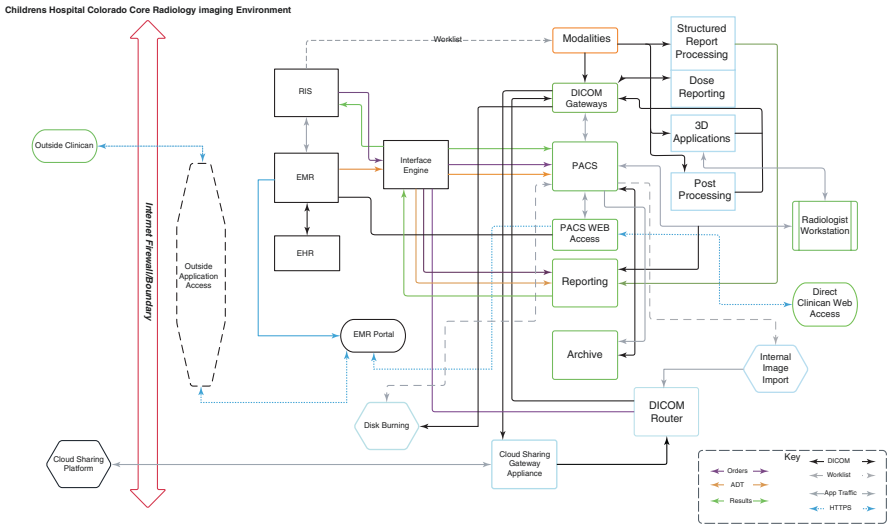

Fig. 9.1 Example of an integrated PACS environment

- The reading stations where radiologists view images are another type of specialized workstation. Although these workstations do not always produce new content for the PACS, there may be annotations or post-processing built into these workstations that need to be permanently stored.

9.3.2 Network

Network design plays a very important role in PACS architecture (see **Chap. 6**). Ideally the network is configured to process PACS traffic on a VLAN (virtual local area network) that is segregated from other enterprise data traffic for increased performance, throughput, and high reliability. This is also important for information security to enable protections on patient health information (PHI) in the event of a security breach.

9.3.3 Archive

A PACS image archive may be hosted in a variety of locations including on-premise in either a designated or shared storage capacity, off-site data centers, and off-site storage within the cloud. The archive should be structurally redundant and physically reside in at least two locations to meet business continuity and disaster recovery needs. Most data archives are built upon various **tiers of storage** determined by organizational structure and needs:

- **Short-term storage** is designed to make data quickly accessible. In an image archive, this is typically where current exam data is housed as well as recently acquired exam data. The information lifecycle management (ILM) timeframe is generally defined by physician requirements. Short-term archives are smaller in size due to the higher costs associated with specified fast-performing storage media.
- **Long-term storage** is generally inactive or infrequently altered. A long-term archive is typically used for older exam data or historical reference data that will seldom be recalled for comparison review. Long-term archives are larger in size due to the lower costs of assigned storage media that offers less performance capability.
- For a more complete discussion of data storage, see **Chap. 7**.

SYNONYMS 9.8: Storage Tiers

Short-term storage = online, near-line, hot, and active
Long-term storage = offline, passive, and cold

KEY CONCEPT 9.6: Network Terms

LAN is a local area network that connects local devices to each other.

WAN is a wide area network that connects LANs to each other.

Gateways are the point of entry for devices external to a defined network, and they act as the protocol convertor which allows data to flow between networks.

Switches connect devices on the network using packet switching to receive and forward data to network destinations.

Routers are devices that analyze the contents of packets transmitted within the network and determine the best route for information to travel.

9.3.4 Database

The database is the heart of a PACS and responsible for the organization and management of images and their associated information within the system. Pertinent data elements included within the database are:

- Patient demographics
- Associated reports
- Study or exam descriptions
- Where the images were obtained
- Where the images are stored in the archive

KEY CONCEPT: Thin vs. Thick Clients

Thick clients are software that is installed on a workstation with strict hardware dependencies. Thin clients generally work through a web browser and do not require specific installation on the workstation.

High-volume PACS environments can benefit from the use of DICOM routers or gateways to evenly distribute image ingestion and export from the archive, and to assist with balancing the workload of the database.

9.3.5 Image Viewers

While the design and means of distribution for PACS image viewing software continues to evolve, this software generally falls under two distinct models:

- Web-based and thin client viewers, often called "clinical" viewers, utilize existing web technologies to render image data for display and are easy to access and manage. Zero-footprint viewers are included here.

FURTHER READING 9.10: PACS Clients

Toland, C., Meenan, C., Toland, M. *et al.* A Suggested Classification Guide for PACS Client Applications: The Five Degrees of Thickness. *J Digit Imaging* 19, 78–83 (2006). https://doi.org/10.1007/s10278-006-0930-z

- Web-deployable or designated workstation thick clients, often called "diagnostic" viewers, have direct licensing and increased hardware dependencies and require more overall support.

9.3.6 Radiology Information System (RIS)

- The RIS is the application that technologists, radiology administrators, and other department staff utilize for most of their daily workflow activities. Staff can enter, edit, and update patient order and exam information in the RIS.
- In an integrated clinical systems environment, the RIS receives and processes initial patient and order information from a HIS, EMR, or EHR.
- The RIS is responsible for generating the unique exam **accession numbers** that are necessary for tracking studies in PACS.
- RIS functionality has been incorporated as a direct module or component of most large medical record systems eliminating the need for a separate system.
- The RIS may also be configured to receive results information from a third-party VR system.
- The protocol the RIS uses for communicating with other systems is Health Level 7 (HL7; see **Chap. 12**).

SYNONYMS: Thin Client

Web-based viewer
Zero-footprint viewer
Clinical viewer

DEFINITION: Accession Number

A unique identifier for a single billable examination. From an accession number, your PACS database can determine which patient, what date, and what type of exam was performed. Sometimes, a single examination is coded with multiple accession numbers, only some of which have associated images.

FURTHER READING 9.13: Enterprise Imaging

Enterprise Imaging White Papers (2020). Society for Imaging Informatics in Medicine. https://siim.org/general/custom.asp?page=himss_siim_white_pap. Accessed 10 Sep 2020.

9.3.7 Interface Engine/PACS Broker

- An interface engine or PACS broker is responsible for processing messaging between PACS and other connected systems such as the RIS, HIS, EMR, EHR, and VR.
- The engine/broker is the bridge that converts HL7 messages into DICOM format, and vice versa.

9.4 Other Image Management Systems

- **EMR/EHR integrated storage**: It is common for EMR/EHR vendors to offer a form of integrated storage, which can also be referred to as **enterprise content management (ECM)**. While primarily used for medical document management, photos like those captured in dermatology or surgical wound care often find a storage home here.

KEY CONCEPT 9.11: HL7

Health Level 7 is a comprehensive framework and related standards for the exchange, integration, sharing, and retrieval of electronic health information that supports clinical practice and the management, delivery, and evaluation of health services (see **Chap. 12**).

- **Departmental or specialty image storage (mini-PACS)**: Different departments or specialties, such as cardiology and ophthalmology, may have their own PACS which are sometimes referred to as "mini-PACS." These systems offer clinicians targeted image review tools, typically with limited capabilities for integrating with the HIS, EMR, or EHR. Alternatively, other departments may piggyback on the full radiology PACS, and store and view their imaging studies there.
- **Point-of-care ultrasound (POCUS)**: POCUS vendors offer focused application software with associated storage configurations designed for use in conjunction with their devices. Elements of the POCUS image-capture workflow differ greatly from traditional PACS workflow, and may require added functions like data entry, reporting, image storage, billing, credentialing, and quality assurance for specialty programs to achieve optimal clinical use.

DEFINITION: POCUS

Ultrasound machines have become small, inexpensive, and safe for non-radiology personnel to use. These machines may be scattered around the hospital and used by other healthcare providers to augment their physical examinations. This is referred to as point-of-care ultrasound.

Enterprise archive or vendor-neutral archive (VNA): Enterprise Imaging strategies have been the driving force behind the increased adoption of enterprise archives and vendor-neutral archives. These repositories are capable of ingesting and storing data objects in both DICOM and non-DICOM formats, allowing for integrated image storage at the enterprise level. Architected to be the core infrastructure of an Enterprise Imaging platform, they enable standards-based services for enterprise-level image management (see **Chap. 7**).

9.5 Imaging Workflow Elements of PACS and Other Image Management Systems

The basic imaging workflow elements that PACS and other image management systems facilitate include:

- Acquisition and storage of studies
- Validation of DICOM and HL7 data
- Retrieval and display of studies and reports by image consumers (i.e., radiologists, other physicians, clinical staff)
- Automated retrieval and display of pertinent comparison studies
- Added support for additional image consumer needs, such as technologist quality assurance or the production of discs for distribution by a digital librarian

DEFINITION 9.14: Nighthawk

Preliminary interpretations provided for studies performed overnight and on weekends. A nighthawk radiologist or reading service is tasked with interpreting studies within a few minutes of receipt, and then sending back preliminary reports. This is a service used by many healthcare organizations, particularly those that do not have radiologists available to provide 24×7 onsite support.

9.6 Valuable Imaging Workflow Advances Made Possible by PACS and Other Image Management Systems

- Integrated programmable peer review
- Asynchronous communication tools, such as those used with ED physicians
- Inclusion of nighthawk reads
- Feedback mechanisms for over-reading of studies, as with resident workflows
- Digital teaching files
- Shared conference or interdisciplinary learning files

OUR EXPERIENCE: Redesigning the Outside Imaging Workflow

At Children's Hospital Colorado, we treat patients from all over the world, and those patients come with prior imaging performed at other institutions. This imaging arrives via various methods including cloud sharing, optical discs, VPNs, and even occasionally physical film. The volume and diversity of outside imaging has warranted an entire team of staff members dedicated to ensuring the studies get ingested and tracked into PACS appropriately. Historically this work was all performed manually, leaving a lot of room for improvement.

Last year a representative from the imaging informatics team was selected to lead a Green Belt process improvement project, with the focus on streamlining the outside imaging workflow. The top complaints being received about the existing workflow came from our physicians and included (1) the need to enter an order for every outside exam upload request and (2) the overall length of time it took from the exam arriving at our door to its availability for review in PACS. The Green Belt project was subsequently designed to solve these two key challenges.

Using a DICOM router and corresponding HL7 tools, a process was created to automate order creation in the EMR/RIS upon receipt of a study, and then appropriately edit and route the updated study directly into production PACS. After extensive assessment, testing, and optimization, the new and improved process was launched this March. There were many positive changes that occurred as a result of this work, but the key areas of impact are below:

1. We eliminated the need for physicians/staff to place an order for any reference study.
2. We reduced the amount of time from exam arrival to review availability in PACS by 94%.

- Incorporated advanced visualization technologies
- Electronic transfer of DICOM imaging with other organizations
- Teleradiology
- Image-based data mining and research

FURTHER READING 9.15: Teaching Files

Siddiqui, KM., Branstetter, BF.: Digital Teaching Files and Education. In: Dreyer, KJ., Hirschorn, DS., Thrall, JH., Mehta, A. (eds.) PACS: A Guide to the Digital Revolution, pp. 495–522. Springer, New York (2006)

PEARLS

- PACS as a concept has been around since the early 1970s, but practical systems were first put in place in the 1990s.
- The core components of a traditional PACS include:
  - Acquisition devices
  - The network
  - The archive
  - The database
  - Image viewers
  - The interface engine/broker
  - Other connected clinical systems like RIS and SR
- Other examples of systems where image management occurs include:
  - EMR/EHR integrated storage (ECM)
  - Departmental or specialty image storage (mini-PACS)
  - Point-of-care ultrasound (POCUS) systems
  - Enterprise archives or vendor-neutral archive (VNA)
- PACS and other image systems have enabled advanced imaging workflows such as:
  - Programmable peer review
  - Asynchronous communication
  - Inclusion of nighthawk interpretations
  - Feedback mechanisms for over-reads
  - Digital teaching files and shared conference files
  - Advanced visualization technology integration
  - Teleradiology
  - Image data mining for research

Self-Assessment Questions

1. The primary functions of PACS are storage, _____, and display of images.

   A. Integration
   B. Distribution
   C. Quality assurance
   D. Interpretation

2. The ACR and _____ are responsible for the creation of the DICOM standard.

   A. SIIM
   B. HIMSS
   C. NEMA
   D. ASNR

3. PACS acquisition devices include modalities such as CT, MR, US, and _____.

   A. Card scanners
   B. Microphones
   C. Keyboards
   D. PET

4. The primary protocol for transmitting medical images from modalities to PACS is:

   A. HL7
   B. IHE
   C. DICOM
   D. HIPAA

5. Which credential is the designated industry-recognized standard for professionals working in the field of imaging informatics?

   A. CISO
   B. DO
   C. CIIP
   D. MCSE

6. The PACS database is responsible for managing which pertinent data elements? Select all that apply:

   A. Patient demographics
   B. Associated reports
   C. Where the images are stored in the archive
   D. Where the images should be sent

7. Though technology continues to evolve, most PACS image viewers can be classified as web-based, thin client, _____, or thick clients.

   A. Browser
   B. Web-deployable
   C. HTML
   D. Solid state

8. Other systems that manage images besides PACS include:

   A. VNA
   B. RIS
   C. VR
   D. CDS

9. PACS provides basic imaging workflow elements such as:

   A. Acquisition and storage of studies
   B. Validation of DICOM and HL7 data
   C. Automated retrieval and display of pertinent comparison studies
   D. All of the above

10. Which of the following advances, when part of PACS or other image management systems, gives attending radiologists the ability to share important or interesting cases with residents for future review?

   A. Integrated programmed peer review
   B. Digital teaching files
   C. Incorporated advanced visualization technologies
   D. Teleradiology