Medical Image Management in Healthcare Enterprise

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Medical Images

Medical images obtained from different image modalities contain vital information about various states of the patient. This information can be used to make diagnosis and to facilitate therapeutic and surgical treatments. Traditionally, these images are stored and viewed from films. During the past 20 years, digital technology has gradually changed the conventional analogue operation to the digital method. Some of the digital imaging modalities include computed radiography (CR) and digital radiography (DR), computed tomography (CT), magnetic resonance imaging (MRI), ultrasound and microscopic imaging (MI). An average US hospital of 500 beds performing 200,000 radiological examinations per year accumulates about 10 gigabytes per day or three to five terabytes per year. Management of these large image files involves picture archiving and communication system (PACS).

In this system, images acquired from modalities are organised in an industrial standardised Digital Imaging and Communications in Medicine (DICOM) data model and are archived and distributed to 10–20 diagnostic workstations, each with multiple 1,000-line display tube (CRT) and/or liquid crystal display (LCD) high-resolution display monitors (cathode ray tube (CRT) and/or liquid crystal display (LCD)) within radiology departments, 20 or more clinical workstations with multiple 1,000-line display monitors at hospital wards and hundreds of desktop workstations throughout the hospitals. A PACS of this scale costs about US$5 million and about 8% of the system cost for service and maintenance per year. This excludes the hospital communication network infrastructure cost and image modality purchases. Figure 1 shows the DICOM work list (left) and some CT images (right) of a CT examination.

PACS

PACS is a work flow-integrated system for managing medical images and related data and is designed to streamline operations throughout the whole patient care delivery process. Effective use of PACS throughout the hospital operation would shorten the time for diagnosis and thus improve the efficiency of healthcare delivery. PACS has become a mature technology during the past five years and has been widely implemented in North America, Europe and most Asian countries.

The PACS concept originated at the The International Society for Optical Engineering (SPIE) Medical Imaging Conference in Newport Beach, CA, in February 1982 and is a system integration of medical images originally designed for facilitating radiologists in interpreting images more efficiently. It has evolved during the years to become a cornerstone of modern healthcare delivery systems. PACS consists of several major components, which are described as follows.

Hospital Information System

A PACS database consists of an imaging subsystem. Medical images obtained from different image modalities is necessary. A database gateway is used for

Database Gateway

PACS requires patient information from HIS/CMS and RIS to direct the radiology operation effectively and efficiently. In order to ensure that patient information is preserved and to avoid human errors, direct connection of these databases to the imaging modalities is necessary. A database gateway is used for
this connectivity. The database gateway transmits a work list of the patient from HIS/CMS or RIS directly to the imaging modalities and PACS (see Figure 1 (left)).

Imaging Modalities

Imaging modalities used in PACS include MR, CT, ultrasound, CR, DR, digital subtraction angiography (DSA), nuclear medicine, microscopy and endoscopy images. After an image or a series of images has been generated from a modality, it is converted to DICOM format and transmitted to other components of the PACS using the DICOM communication protocol.

Acquisition Gateway

For those modalities that do not convert images to DICOM standard, the images are routed to an acquisition gateway where they are converted to DICOM standard. The gateway is also used to stage images from different modalities as a buffer before they are sent to the PACS controller.

PACS Controller – Image Database and Archive

Images from the acquisition gateway are sent to the PACS controller – an image database and an archive server. Images are archived according to the DICOM data model and distributed to workstations.

Workstations

There are three types of workstation: diagnostic (very high resolution with 2,500 lines x 2,000 pixels), clinical (medium resolution with 2,000 x 1,600) and desktop (from 1,000 to standard 800-line display). Figure 1 shows a diagnostic workstation with CT images at right and the patient work list at left. Radiologists make the diagnosis at the workstation and the report is sent to the RIS/HIS/CMS.

Application Servers

Selected images from the PACS controller can be sent to various application servers. These servers can be a standard server or Web-based server for PACS-based image distribution for clinical, education and research applications.

Rationale of Using Image Distribution and PACS in Healthcare Delivery

The rationale of using PACS for image distribution has been documented for over 10 years. Table 1 summarises the benefits of using PACS in healthcare delivery.

HIS/CMS and Electronic Patient Record

Both the HIS and CMS described here are hospital or clinic-based, not designed for individual patient usage. A recent trend is to replace HIS/CMS with an electronic patient record (EPR), a more patient-centred database system. EPR is an emerging concept to replace or supplement the hospital or clinic-based healthcare information system. The concept of EPR is that when a patient requires clinical services, the patient’s data ‘follows’ them anywhere in the healthcare delivery chain. Major functions of EPR are to:

- accept direct digital input of patient data;
- analyse patient and provider profiles;
- provide clinical decision support and suggest courses of treatment;
- perform outcome analysis and patient and physician profiling; and
- distribute information across different data platforms and health information systems.

Coupling the concept of EPR with the image data in PACS results in a very powerful tool to distribute image-related data of a patient when it is needed.

Enterprise Level Image/ Data Distribution

Teleradiology

When PACS is used within a hospital, image and related data distribution is based on local area network (LAN) technology. When PACS is used across hospitals, image distribution is based on wide area network (WAN) technology (sometimes referred to as teleradiology). Teleradiology was originally designed for radiologists to review cases at home or other locations as needed. However, over the years, it has evolved into a network of radiology expert services. In this scenario, a group of radiologists from an expert centre, clinics and hospitals send their radiology examinations to the centre for review.
**Enterprise-level Image/Data Distribution**

An enterprise-level healthcare system is formed by many hospitals and clinics sharing resources and patients. Patients and their records and services can be exchanged between each entity. In this situation, image/data distribution using the EPR concept and the established PACS and teleradiology expert centre arrangement is essential for the operation. Figure 2 shows the EPR concept in enterprise-level image/data distribution. In this set-up, patient images and related data are accumulated and distributed within each hospital using its own PACS. Relevant patients’ images/data are filtered and a patient identification cross-reference check is performed to ensure that the patient belongs to the enterprise. Images/data are then sent to the enterprise-level Web-based EPR server for archive. Web clients anywhere in any hospital belonging to the enterprise can access the patient image/data record.

**Business Models for Image/Data Management in the Enterprise Level**

An average PACS per hospital costs US$5 million plus 8% service and maintenance per year. Enterprise-level image distribution is a very large-scale system integration project. It can be extrapolated that the investment for image management at the enterprise level would be quite substantial. There are several possible business models available as follows.

- **Outright purchase with maintenance contract** – the enterprise provides the finance for PACS equipment purchase and annual maintenance and also plans and designs the system. A system integrator would be responsible for implementation, training, service and system upgrade. The enterprise would run the daily operation.

<table>
<thead>
<tr>
<th>Table 1: Visible (Tangible) and Invisible Benefits of Using PACS in Healthcare Delivery</th>
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<tbody>
<tr>
<td><strong>Visible Benefits of PACS</strong></td>
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<tr>
<td>Cost Saving</td>
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<td>• Film and chemical</td>
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<tr>
<td>• Film and chemical management cost</td>
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<tr>
<td>• Reduce manpower for film handling</td>
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<tr>
<td>• Save storage space</td>
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<tr>
<td>Improve Productivity</td>
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<tr>
<td>• Faster turnaround time</td>
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<tr>
<td>• Save patient waiting time</td>
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<tr>
<td>• Reduce retake rate</td>
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<td>• Save patient return visit</td>
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**Invisible Benefits of PACS**

- Better quality control
- Promote local IT industry
- Reduce pollution

In every hospital or specialized practice, a veritable flood of medical imaging data is generated every day. This flood must be systematically organized, archived, and often made available to several workstations for diagnosis. Here the speed, security of the data, and the simplest operation possible play the leading role. You concentrate on the diagnosis; we’ll take care of your data management! We care about your image.
• Outsourcing – the enterprise outsources the complete system from planning, design and implementation to operation to the outsourced company.

• Application service provider (ASP) model – an ASP model can be small or large. It can support either the complete image management system or subsets of the project, for example supporting off-site archive, long-term image archive/retrieval or second copy archive, DICOM Web EPR server development and Web-based image database.

• Pay-per-procedure – this model is for a system integrator to take over the complete enterprise image management. The system integrator charges the enterprise a fee per use.

• Software purchase only – a new model is software purchase only. The enterprise first designs the image management system architecture including hardware and workstation. The enterprise then decides what software can be implemented in-house and what needs to be purchased. The enterprise then negotiates with a manufacturer to procure additional necessary software. The procurement would include software licensing, installation, upgrade, training and maintenance. The enterprise purchases its own hardware. The VAHE’s VisitA imaging component uses this model for those VA hospitals that do not want to purchase a PACS from a manufacturer but want direct support from the VA information technology (IT) department. VAHE then purchases the software and designs the image distribution for the hospital with compliance as shown in Figure 2.

• Loosely coupled partnership – loosely coupled partnership is defined as the enterprise forming a partnership with a system integrator. The partners share some defined responsibility in the planning, design, implementation and operation. The procurement is similar to the outright purchase but with a favourable discount because of certain contributions from the enterprise. This model is currently in use by many PACS installations. However, most of these partnerships are for one-time installation between hospital and the manufacturer. For enterprise-level image distribution, the tightly coupled partnership described here is more suitable for the enterprise to adopt.

• Tightly coupled partnership – in order for the tightly coupled partnership to be beneficial to both the enterprise and the system integrator, certain responsibility from both partners is necessary.

  – Both the enterprise and the integrator should make a long-term commitment, say five years, to support the image distribution project. The commitment includes technical, personnel, financial and ethical aspects.

  – In the technical aspect, both parties should share confidential technical materials related to the project. The manufacturer should guarantee that the equipment and software uses up-to-date technology by periodic review.

  – In the personnel aspect, both parties should share personnel responsibility towards the completion of the project, as well as in manpower resource distribution and requirement. The integrator should provide adequate training to the enterprise personnel to ensure engineering and operation sufficiency – defined as the enterprise’s ability to install subsequent systems independently.

  – In the financial aspect, the enterprise has the responsibility to guarantee a mutually agreeable payment to the integrator annually. In return, the integrator has the responsibility to guarantee that the image distribution would satisfy the enterprise image/data work flow requirement and that the equipment would be up to date after a period of, say, five years.

  – In the ethical issue, both partners must abide by the ethical code of a tightly coupled partnership recognised by the IT and medical communities.

  – The tightly coupled partnership model is the current preferred method for implementing large-scale enterprise-level image distribution.

Additional Information

The complete version of this article, including additional graphics, table and references, can be found in the Reference Section on the CD-ROM accompanying this business briefing.