Picture Archival and Communications System (PACS) and the Ultrasound Department

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With the increase in the speed of computers and a reduction in the cost of computer hardware, PACS is desirable as it improves efficiency and workflow by enabling the operators to view current and previous examinations and reports simultaneously, to retrieve previous exams faster and more reliably (no more lost film packets), and to eliminate the need to print on film and to file or distribute films manually.2 PACS can be departmental (often known as a mini-PACS) or hospital-wide as in the filmless hospital.2 PACS has been around since the early 1990s, the early systems were very expensive and difficult to integrate into a busy department. The systems have evolved due to the development of digital compatibility, the reduction in hardware cost, and an increase in the speed of the computers and networks.1 PACS is a network of computers, which are integrated to allow diagnostic images and patient information to be displayed on computers screens, and remove the need to print on film and to file or distribute films manually.1 PACS can be departmental (often known as a mini-PACS) or hospital-wide as in the filmless hospital.2 PACS is a network of computers, which are integrated to allow diagnostic images and patient information to be displayed on computers screens, and remove the need to print on film and to file or distribute films manually.1 PACS can be departmental (often known as a mini-PACS) or hospital-wide as in the filmless hospital.2 PACS has been around since the early 1990s, the early systems were very expensive and difficult to integrate into a busy department. The systems have evolved due to the development of digital compatibility, the reduction in hardware cost, and an increase in the speed of the computers and networks.1 PACS is a more viable, although still relatively expensive option, for many Trusts. As part of the National Programme for Information technology (NPfIT) the government has pledged to install PACS in all major hospitals in England and the PACS should be fully available nationally by 2007.7 PACS is desirable as it improves efficiency and workflow by enabling the operators to view current and previous examinations and reports simultaneously, to retrieve previous exams faster and more reliably (no more lost film packets), and to eliminate the need to print on film and to file or distribute films manually. Examinations can also be reviewed remotely and concurrently by multiple users. This improvement in efficiency benefits the patients by enabling faster diagnoses and, therefore, hopefully quicker treatment. The initial cost of installation is high, but there are savings on chemical and film costs, and with increased efficacy, the NHS can save money with shorter lengths of stay in hospital. The purpose of this article is to describe the various components of PACS and to relate them to the ultrasound user. When considering the purchase of PACS, various components must be taken into account as PACS is a network of systems, which must integrate well to ensure efficient flow of information occurs (see Table 1):

- Image acquisition: in order for diagnostic images to be displayed on a PACS, the images must be acquired in a digital format.
- Patient information interfaces: a effective radiology information system (RIS) and hospital information system (HIS) are essential components of PACS to ensure that the patient information correlates with the image.
- Image display: examinations can be displayed on dedicated diagnostic PACS workstations in the imaging dept or on PC web-browser.
- Storage: the storage of the information and the ability to retrieve previous examinations fast and efficiently.

The components of PACS communicate by a network of fast cables to the database server, a central computer that tracks the patient and examinations information as illustrated in Fig. 1. The purpose of the components are described in greater detail.

Imaging Acquisition

Most imaging modalities acquire images in a digital format, e.g. computed tomography (CT), ultrasound, magnetic resonance imaging (MRI), nuclear medicine, digital radiography, digital angiography and fluoroscopy. In order for the digital information acquired is transferred to the PACS, the imaging device, e.g. ultrasound machine, must be able to communicate effectively with PACS, this term is described as being DICOM (Digital Imaging Communications in Medicine) compatible. DICOM is a standard initially developed by a joint committee of the American College of Radiology and the National Electrical Manufacturers’ Association (ACR/NEMA) to standardize the digital communication of information. The committee encouraged all manufacturers of imaging equipment to adhere to this standard to ensure that a common language was used to enable imaging equipment by various manufacturers to integrate with PACS.5

The ultrasound machine connects to PACS by an Ethernet cable, which extends from the machine to a PACS drop, which is similar to a phone point that is normally placed on a wall as demonstrated in Fig. 2. Where equipment is older and not DICOM compatible, analogue to digital conversion is required to communicate with the PACS system. If the ultrasound equipment is not DICOM compatible, the images can be recorded using the frame grabber from the video output of the machine. This method is not ideal as the ultrasound image is degraded due to loss of pixels and frame grabbing is less reliable than a direct connection to PACS.6

The imaging device (ultrasound machine) should also communicate with the radiological information system via the Ethernet cable, this is to enable patient information to be displayed on each machine in a modality work list. A modality work list is a list of the patients and examinations that are currently scheduled to take place (see Fig. 3). By selecting each examination of the work list, the images can be acquired into the correct patient folder thus merging the patient details...
and the images, and ensuring that they are correctly acquired onto PACS. This reduces clerical errors, such as misspelling names and mistyping patient identity numbers, which may result in generating two patient entries on PACS for one real patient. In ultrasound the modality work list can generally be updated manually by selecting the update or replenish button on the patient demographics page of the ultrasound machine.

In summary when purchasing ultrasound equipment for integration into a PACS, the machine should be DICOM compatible and the DICOM conformance statement should be requested from the supplier or obtained from the internet. The machine system should handle patient files, demographics and images in DICOM file format within the machine, and also be able to output DICOM data to PACS. The modality work list must be included and enabled on the system.\textsuperscript{6}

**Patient Information Interfaces**

Most hospitals have a computerized patient information system commonly called hospital information system (HIS), which deals with patient identity, patient tracking and clinical results from various departments, hospital wide. Imaging and ultrasound departments tend to have a departmental computerized system, which contains patient demographics, examination scheduling and examination reports this is generally known as a radiology information system (RIS).\textsuperscript{2} When considering the purchase of PACS on a departmental level or to provide hospital-wide access, the HIS and RIS must be included in the decision and this requires the input of the hospital information technology (IT) team.

As previously stated the RIS should communicate with the imaging device and display a Modality work list on the system screen. The RIS should also communicate directly with PACS as PACS relies on the RIS to update the patient and examination information. Communication between PACS and RIS is generally via an interface tool known as a broker. In common with the imaging device the RIS informs PACS of the examinations scheduled. Reliable interfaces are essential for smooth functioning of the system.\textsuperscript{1} All changes to patient information should be recorded on the HIS/RIS, which imparts this information to PACS.

**Image Display**

When the images are transferred to PACS, they are displayed on high-resolution computers screens known as workstations. The resolution of the PACS workstation is dependent on the use of the workstation, e.g. a radiologist reporting a chest X-ray requires a much higher resolution monitor than the clinician reviewing the same chest X-ray.\textsuperscript{2} Radiologists reporting plain radiographic images tend to report from workstations generally 1728 x 2304 pixels. These high-resolution monitors display images in greyscale and therefore colour Doppler images should ideally be available for review in colour as flow directions are impossible to distinguish in shades of grey; therefore, some of the PACS workstations purchased should permit the colour shades to be displayed.\textsuperscript{6} Figures 4 and 5 demonstrates how directional information is lost on greyscale monitors.

Workstations that enable colour display are of lower resolution (1280 x 1024 pixels) than greyscale monitors, this not an problem as ultrasound is a dynamic modality, where the diagnostic information is acquired in real time by the operator who is generally the reporter of the examination. Therefore, in an ultrasound department, workstations that display colour images are an important component in purchase. In the hospital-wide PACS, examinations are displayed on the wards...
and the clinics using web-browsers on PCs that are capable of displaying colour images.

How the examinations are displayed on the workstations is also an important consideration. The utilization of work lists and subfolders helps the user display the information in a concise manner depending on whether they are reviewing or reporting the examinations. Work lists are ideal when reporting: they provide a list of the unreported examinations and can be subdivided into modalities, thus enabling the sonographer to select the unreported ultrasound work list more easily. Clinical folders provide history of all the patients previous examinations.

Another parameter displayed with the patient information is the status of the examination. This information lets the viewer know whether the examination has been performed and all the images successfully transferred to PACS, whether the report has been dictated and verified.

Another benefit of the PACS workstation software is the ability to adjust contrast, brightness and magnification. The toolbar also enables annotation to be added, and measurements and angles can be assessed. This is particularly useful when performing ultrasound on paediatric hips to assess the alpha and beta angles on line. If more extensive measurements, such as velocity of blood flow, is required then a mini-PACS would be more useful.

**Storage Devices**

Once the examination is transferred to PACS, and displayed for reviewing and reporting, the information must be stored for retrieval in the future if required. One aspect of an efficient and effective PACS system is its speed. When reporting or viewing an examination, the operator (sonographer, radiologist) requires an immediate response from the system to provide information about previous examinations. In order to facilitate this flow of information, storage or archiving is generally divided into short- and long-term archiving. Short-term storage enables the fast retrieval of recent examinations and usually this data is held on arrays of fast hard disc drives, known as a redundant array of independent disks (RAID).²

Long-term archiving is usually on some form of optical or magnetic media. If the capacity of the short-term storage (the RAID) is limited, then older examinations will need to be transferred from the longer-term storage. The retrieval of older examinations from the long-term archive can improved by using prefetching algorithms HIS/RIS to instruct PACS when a patient becomes ‘active’, for example, when examinations or hospital visit are scheduled. If there is ample fast short-term storage then such prefetching is not required. The technology for archiving is continually changing, on line storage is now currently available.

The stored ultrasound image information is also compressed to reduce storage space, which can be done in a lossless manner. A study undertaken by Persons et al. (2002) showed that even when irreversible compression is applied to clinical ultrasound images no image quality-related issues were encountered.²

When examinations need to be downloaded from PACS when patients are transferred to other institutes or for teaching purposes many departments use dry-laser imagers or paper, others use CDs. CDs are a very inexpensive option and requires a CD reader to be attached to PACS.

**Ultrasound Considerations**

Ultrasound imaging requirements from PACS can differ from other modalities particularly in respect of the volume of data acquired,

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Figure 4. (a) Greyscale image of flow in the femoral vein, no directional information is displayed. (b) Colour image showing directional flow in leg vessels. (c) Greyscale image of flow in the portal vein, spectral trace is required to provide directional information. (d) Colour image showing portal vein with hepatopetal flow.
colour Doppler imaging and cine clips. Ultrasound imaging is also used by a variety of professionals in different specialties, e.g. obstetrics, general imaging and echocardiography. Each ultrasound speciality has its own clinical requirements: the volume and type of images acquired and stored varies, e.g. in echo-cardiology large volume of real time images are acquired due to the nature of the fast frames rates used.

When considering a PACS purchase the decision of whether a contained departmental system (mini-PACS) or a hospital wide-system is required can be dictated by the ultrasound speciality, the volume of examinations and whether remote viewing by clinicians is required. The data volume acquired in a typical examination is generally small, amounting to a few dozen images, though large cine clips are stored in echocardiography, contrast ultrasound imaging and 3D ultrasound. The large size of cine clips posed a problem for PACS due to software limitations and, in the past, many departments considered mini-PACS to store cine clips. Recent software advances permit multiframe image storage, which allows cineclips to be stored and played as a movie clip on PACS.

In the research setting where quantitative analysis such as time intensity curves and wash in curves may be required, mini-PACS is more desirable as these measurements are generally available on a hospital wide PACS. Another aspect to consider in the research setting or when using ultrasound images for publications or teaching is that the patient demographics are ‘burnt’ on the image and form part of the image. For other modalities, such as CT and MR, the patient demographics is displayed in the DICOM header and not on the images, and therefore can easily be removed. However, ultrasound images require masking using computer software prior to ensure patient anonymity. The ultrasound machine can be set up by the engineer to record only the ultrasound image and not include the patient demographics on PACS. However, this option is not ideal as none of the patient identity is on the image and this can potentially lead to errors.

PACS downtime can occur due to failures of certain components or due to upgrading or maintenance of the system. In order to ensure the smooth running of the department when problems arise with the RIS, the ultrasound machine should be...
Summary Points

Factors that should be considered when purchasing PACS

- Are the ultrasound machines DICOM compatible? If so, should the equipment be replaced or how reliable would digital-analogue conversion be?
- How effective is the RIS/HIS, will it integrate with PACS?
- Is a mini-PACS or a hospital-wide PACS most appropriate?
- Do you acquire a lot of colour Doppler images that require colour monitors?
- Do you acquire large cine clips? Do you need to perform quantitative analysis?
- What is the volume of workload, and how much short- or longer-term storage is required?

able to function without the modality work list, although caution is needed to reduce mistyping patient details.

In order to eliminate the risk of loss of images when acquiring ultrasound images, all images should ideally be stored on the hard drive of the machine prior to transferring to PACS. This is particularly useful as PACS is down, and the when performing portable ultrasound examinations as the images can be transferred when PACS is up and running or for the latter when the machine is reconnected to PACS. The down side of storing on the hard drive, as well as sending to PACS is that older examinations need to be erased from the hard drive.

The age of the ultrasound equipment should be considered when installing PACS. Although non-digital ultrasound machines can be linked to PACS by analogue-digital conversion, the images are suboptimal and older equipment may need to be replaced or upgraded. DICOM compatibility is truly essential to ensure the most of PACS technology.

Summary

With the national programme for information technology, all major hospitals in England should have PACS by 2007. The installation of PACS is expensive as it requires the integration of various computerized components. In order to store images on PACS the must be acquired in a Digital format. The ultrasound department has specific requirements, such as the display of colour images and cine clips, which can be incorporate into the PACS purchase.

References

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