THOPACS : The Multi-Modality, Image Review Diagnosis, Archiving and Analysis System

N van der Putten, S de Winter, M de Wijs, R Hamers

Erasmus Medical Center, Rotterdam, The Netherlands

Abstract

We have developed and introduced a digital multi-modality image infrastructure in a multi-vender networked environment. This cardiology PACS (THOPACS) provides facilities for network communication between all DICOM-image generating systems in the Thoraxcentre. It facilitates hospital-wide access to all cardiology images and analysis results. THOPACS is integrated in the medical workstation of our hospital offering simultaneous presentation of images and related reports along with test results. This paper focuses mainly on the solutions for handling huge datasets, the archiving strategy, the automatic uploading of images from other hospitals, workflow support and the interoperability with image analysis systems.

1. Introduction

Digital echocardiography and angiography have changed the clinical workflow in the last decade. The ability to have direct access to medical images for diagnosis, interpretation and review is a very useful capability in clinical practice. In the Thoraxcentre in Rotterdam the images of 7 echo-machines, 5 Cathlab X-ray systems and 2 IVUS systems have been archived in our THOPACS system for many years.[1] This system has been developed by CURAD (Wijk bij Duurstede, NL) in cooperation with the Thoraxcentre. It is a networked digital archive that stores, manages, transmits and displays cardiology images. Basically, the digital images generated during an echocardiographic or catheterization procedure are sent to a server, designed specifically to store DICOM compliant images. All clinicians are able to access the images at any location in the hospital. Access to the images has been extended to a physician's home using VPN and to other hospitals in the Rotterdam region using the EVOCS system (a web application for exchanging DICOM images between hospitals). Until recently the Thoraxcentre generated 800 GB image data a year. A number of significant changes have dramatically reshaped our image landscape. The changes have extended our yearly image data production to 6 TB data. In the Cathlab the flat panel detector technology has been introduced. Instead of images with a resolution of 512*512 pixels of 8 bits much larger images until a resolution 2048*2048 pixels of 12 bits may be generated. New technologies like CT-mode scanning and new medical procedures in the Cathlab like Aortic valve replacement increased the number of images per procedure. In the Echocardiography department the routine utilization of 3D- and 4D-images in clinical practice has extended the average study size from 30 MB 2D-image datasets into 200 MB 3D-image datasets. Especially the introduction of larger angiographic images has enormous consequences for network, computer, computer screen and archiving strategy. In addition workflow support and reporting capabilities and functions become important features in cardiology PACS installations. In this paper we will outline the critical components and strategies of this multi-modality cardiology PACS. We put forth some of the pitfalls that we have encountered in our own implementation.

2. Methods

There are several convergent trends in technology that can be integrated to improve quality and ability of images in the cardiologic practice. Examples are: faster servers, bigger network bandwidth, falling storage costs, better compression algorithms, and the implementation of standards for image and report storage and communication in almost all medical devices. In the next paragraphs the application of these techniques in dedicated parts of THOPACS are described.

2.1. General architecture

THOPACS consists of dedicated clinical, research and 3D-image systems. The clinical THOPACS system runs on 6 blade servers. The 4 application servers are connecting both the X-ray devices in the cathlabs and the echocardiographs in the main echo lab, the OR's, the wards and the intervention rooms to the storage system. This allows storage of all image data throughout the Thoraxcentre into a central enterprise storage area network (SAN). The other blade servers are functioning as database manager to facilitate the querying and retrieval of the DICOM images based on a configurable set of DICOM attributes. The blade servers are connected to the SAN through a high speed fibre optics channel network (see fig. 1). THOPACS facilitates automatic import of images from CD and from the regional image server (see 2.7).

Images may be automatically published from THOPACS on DVD through the Ultima DVD publisher (GE-medical).

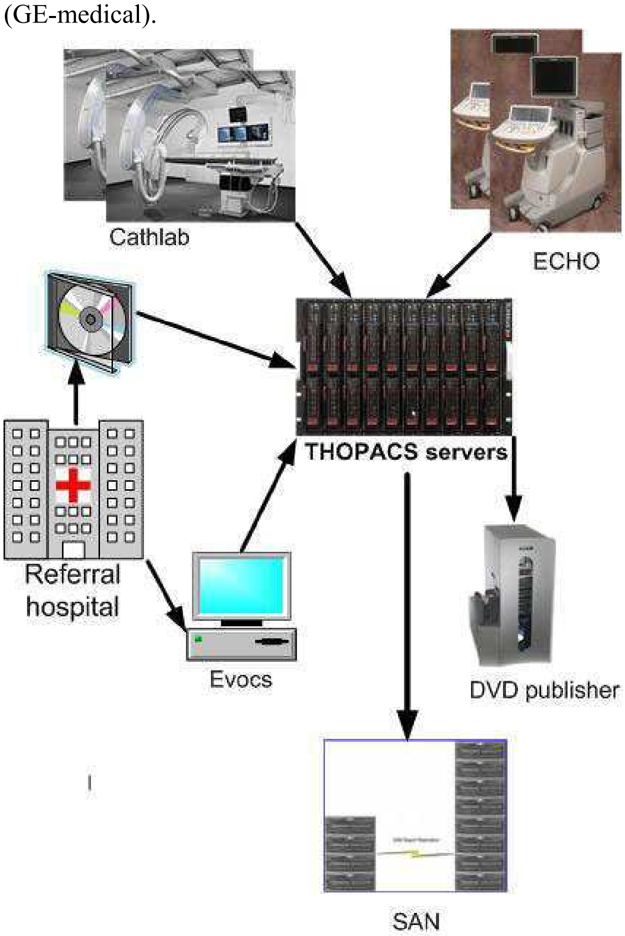

Figure 1. General architecture of the clinical THOPACS system.

2.2. Specific features for the catheterization images

The contemporary cathlab is very often a collection of independent computerized systems for individual tasks such as hemodynamic analysis, digital angiography, quantitative coronary angiography (QCA) or ancillary imaging and quantitative analysis systems (e.g. intravascular ultrasound, IVUS, and quantitative coronary ultrasound, QCU). Only during the interventional catheter treatment many cathlabs have the opportunity to review angiographic images and quantitative results simultaneously. At this moment the angiographic images and related reports (in DICOM secondary capture format) are stored in the clinical THOPACS system. From the THOPACS system the QCA-analysis system (CAAS V; PIE Medical) can be launched to analyze the selected images. We are currently developing software both to archive the QCA-files in DICOM structured report format and to extract relevant QCA-results from the QCA-file into a database. This facilitates the hospital-wide simultaneous review of angiographic images and related QCA-results.

The flat panel detector technology has been recently introduced in our cathlabs. Instead of images with a resolution of 512*512 pixels of 8 bits much larger images up to a resolution 2048*2048 pixels of 12 bits may be generated. Bandwidth is a main issue for these images. E.g.: two related biplane images with a resolution of 1024*1024*12 bits contain 2*16 Mbit data per frame. With a frame rate of 15 or 30 frames per second and a compression factor of 2 a 1 Gbit network is barely capable to transport these images at acquisition speed from the PACS server into the memory of the viewing station. Of course the presentation of these images requires a fast graphic adapter and a large screen with a width of at least 2048 pixels. The storage requirements for 1024*1024*12 bits images are enlarged with a factor 8 compared to the requirements for the storage of 512*512*8 bits images. Besides new technologies like CT-mode scanning and new medical procedures in the Cathlab like Aortic valve replacement increased the number of images per procedure.

To optimize the workflow and efficiency the digital flat panel images are sent to the archive immediately after acquisition. The DVD publisher automatically produces a copy of all image runs on DVD.

The IVUS images and the QCU results are stored in the research THOPACS system. These images may be also reviewed from the clinical THOPACS system. The IVUS system has been described elsewhere. [2]

2.3. 12-Bits images and compression

As mentioned above the images in original format require generous bandwidth, which is not everywhere available in our hospital. Compression and/or downsizing of the images were required. Because downsizing of the images may cause loss of information, we have chosen for compression. JPEG and JPEG2000 are accepted standards in DICOM.[3] JPEG compression with a quality factor of 85% is broadly accepted. JPEG 2000 has many characteristics which are useful for angiographic images. E.g.: JPEG2000 supports 8, 12 and 16 bit grayscale image data. The most JPEG algorithms support only 8 bit grayscale image data. Unfortunately limited information is available about the evaluation results of the utilization of JPEG2000 for 12 bit angiographic image data. A level of compression of about 10:1; i.e.: a quality factor of 85% will speed up network transfer and system response during image browsing significantly.

2.4. Specific features for the echocardiography images

The image server is connecting echocardiographs of different vendors. Examinations from the echocardiographs in the main echolab, the OR's, the wards and the intervention rooms are transferred to THOPACS. The three IE33 echocardiographs from Philips transfer 2D-images to the 2D server (i.e. the clinical THOPACS server in figure 1) and the 3D-images to the THOPACS 3D-server. The 3D-images are also transferred for analysis from the IE33 through the network to Image Arena workstations from Tomtec and to the QLAB workstation from Philips (figure 2). After the analysis of the 3D images the Image Arena workstations transfer the analysis results as DSR or secondary capture to THOPACS. This facilitates hospital-wide simultaneous presentation of the echocardiographic images (2D and/or 3D) and the related analysis results.

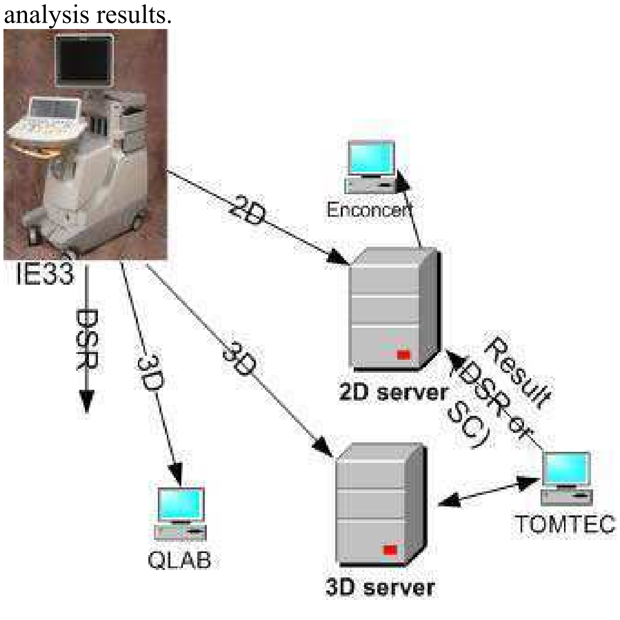

Figure 2. Communication between the echocardiograph IE33, the THOPACS servers and the analysis systems.

Plans are currently underway to extract the analysis results from the DSR report files, which have been transferred from the echocardiographs to THOPACS. This will enable us to extend the image database with measurements, calculations and reports.

2.5. Communication with referral hospitals

In 2006 the ten hospitals in the Rotterdam region have decided to employ the EVOCS system from Fysicon for exchanging DICOM images between hospitals. In the first year this system was used for only 180 angiographic procedures. Now almost all angiographic and just a few echocardiographic images are exchanged through the EVOCS system. However, the medical triage and diagnosis of a referred patient was hampered by the number of different images viewers to be deployed: the web based EVOCS viewer for the angiographic images from the referral hospital, the THOPACS viewer for the Thoraxcentre images and sometimes other viewers for the MRI, CT or chest images. We have limited the number of viewers by a semi-automatic transfer of the EVOCS images to THOPACS.

2.6. Storage strategy

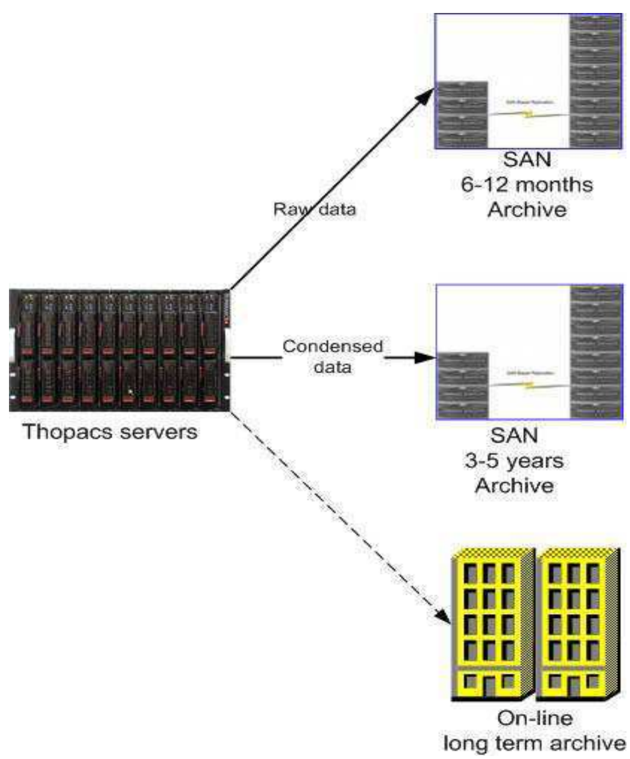

Figure 3. Overview of the three-level storage strategy.

We introduced a three-level online storage strategy (figure 3). In the first level all images are archived in diagnostic quality (i.e.: the original images in raw data format) for 6-18 months. These images are only accessible at dedicated working places. All images are also archived in compressed format for a period of 3-5 years. These compressed images are accessible in every working place inside or outside the hospital. After this period the images will be archived on an online accessible external storage device. This external storage is shared with radiology.

3. Results

THOPACS is now operational for 8 years. At this moment we archive 2D-images of about 7500 echocardiographic procedures and 3D-images of about 2000 echocardiographic procedures per year. In the year 2001 the average study 2D-image data set was about 30 MB and now 80 MB. The routine utilization of 3D and 4D images in the clinical practice requires an average study size dataset of about 200 MB.

The Cathlab X-ray images of about 3000 XA-studies and 1500 IVUS-studies per year are archived. The number of studies is stable. The average size of the image dataset of the XA-studies has been extended with a factor of 8 (from 200 MB into 1.5 GB per dataset); mainly by the enlargement of the size of the images. New technologies like CT-mode scanning and new medical procedures in the Cathlab like Aortic valve replacement also increased the number of images per procedure.

4. Discussion and conclusions

4.1. Department or enterprise PACS?

The majority of cardiology PACS solutions continue to be installed into catheterization and echocardiology laboratories. These systems are used for cathlab or echolab imaging and are totally separate with their own archive, storage and management system. We have chosen for the combined storage of all cardiology images and results. This may facilitate the simultaneous presentation of angiographic and echocardiographic images and results. The next step may be one PACS for radiology and cardiology. However, the differences in cardiology versus radiology workflow demand that they have a separate front-end system with dedicated workstations using cardiac software for display and reading of both echocardiographic and angiographic images. It is of course wise to share storage hardware with radiology to benefit from economies of scale.

4.2. How to display biplane images?

Siemens has developed the Artis zee biplane system with mixed detectors (30*40 and 20*20). This system produces related biplane images with a different resolution. E.g. one image of 1024*1024 and one image of 720*720 pixels. The presentation of these images is still a subject of discussion.

4.3. Technical infrastructure challenges

The application of large X-ray moving images in clinical practice requires dedicated technical infrastructure. Until recently dedicated workstations were used for diagnostic image viewing and ordinary desktop PC's for image reviewing. The dedicated workstations typically include a high-resolution monitor (flat panel or cathode ray tube), a high-performance graphics adapter, and a personal computer platform. These displays are not ordinary desktop PCs.

As already discussed reviewing of two compressed biplane images in a 1k*1K size requires high-resolution displays (typically at least two-megapixel), a network with a bandwidth of at least 100 Mb/sec, and a high-performance graphics adapter. The technical and financial consequences are enormous as reviewing of cathlab images is enabled on every clinical PC in our hospital. Besides, the images are also transferred to the referral hospital. It is unknown if the referral clinicians in other hospitals are able to display cathlab images in a 1K*1K size. We envisage the solution that management systems might route images of varying size to workstations with knowledge of their display attributes.

References

[1] Putten, N van der, Hamers R, Nelwan S, Vletter W, Cate F ten, Dijk W, Baljon M. Desktop Echocardiography. In: Computers in Cardiology 2002; IEEE Computer Society Press, 2002; 341-344.

[2] Hamers R, Bruining N, Knook M, Sabate M, Roelandt JRTC. A Novel Approach to Quantitative Analysis of Intra Vascular Ultrasound Images. In: Computers in Cardiology 2001 ; IEEE Computer Society Press, 2001; 589-592.

[3] http://www.dclunie.com/dicom-status/status.html.

Address for correspondence
Niek van der Putten
Erasmus MC, Thoraxcentre, Ba563
Postbus 2040
3000 CA Rotterdam
n.h.j.j.vanderputten@erasmusmc.nl