Trials and Tribulations in Deploying Digital Imaging Network and Picture Archiving and Communication System—Film to Filmless in 80 Days

Laurence F. Parr, Phillip L. Liotta, Brendan K. Glennon, and Amanda L. Anderson

The Naval Medical Center Portsmouth (NMCP) was constructed with the intention of deploying a picture archiving and communications system (PACS). All necessary infrastructures were installed and considerable planning was done during construction with the belief that this would make the deployment of the PACS much simpler. This was true during the early deployment; however, as time passed and the system was more heavily used, significant problems arose. User/operator-related and hardware/software-related problems were encountered. Although, most have been corrected, some have persisted and will require considerable manpower and/or fiscal resources to correct. The lesson learned is that no matter how much preparation is done for deploying PACS, many significant problems will surface as the system is used that will require the continued attention of the deployment project officer.

This is a US government work. There are no restrictions on its use.

IN THE EARLY 1990s, the Department of Defense (DoD) initiated a contract action to provide picture archiving and communication systems (PACS) to the DoD. This initial effort led to the Medical Diagnostic Imaging Support System (MDIS) contract. These systems, as many PACS of the day, were expensive and, therefore, due to economic reasons, not widely deployed. Since that time, computer developments, better understanding of the problem, and cost reductions in hardware have generated a more favorable environment for PACS and deployment of PACS has gained momentum.

In 1995 the Naval Medical Center Portsmouth (NMCP) was constructing a new medical center that included funding for a PACS. For various reasons the purchase of an MDIS system was not considered appropriate and an initiative was started to find an alternative. This coincided with other similar efforts within DoD and eventually led to the formation of a team to develop a new contract for PACS that became known as Digital Imaging Network and Picture Archiving and Communication System (DINPACS). In 1997 a multivendor contract to provide DINPACS to the DoD was awarded to two vendors: AGFA (Ridgefield, NJ) and IBM (Armonk, NY).

NMCP purchased its PACS from this contract,

selecting the IBM PowerPacs solution. Functioning as an integrator, IBM brought together several other vendors each providing a specific piece of the solution. The contract specifically required commercial off-the-shelf (COTS) components in an effort to eliminate problems associated to proprietary implementations. It was naively thought that the deployment of the PACS would be relatively straightforward in a new facility with an installed network infrastructure, new imaging modalities mandated to be Digital Imaging and Communications in Medicine (DICOM)-compliant, and 4 lead-time months before the facility was due to open. It was our intention to open the hospital filmless. In the final analysis, this installation confirmed many of the trials and tribulations common to prior PACS system installations and identified some new ones.

NMCP DINPACS DESCRIPTION

The Radiology Department was constructed with a large computer room and extensive fiber installed in preparation for PACS. This room provides ample space for the present system with room to grow in support of other DoD facilities located in the region. DINPACS is composed of six functional components: an archive, a full commercial radiology information system (RIS), workstations, a web server, a teleradiology server, and a dedicated asynchronous transfer mode (ATM) network.

The archive is composed of long-term and intermediate-term storage. The long-term storage is provided by four IBM 3995 C68 towers capable of 5.3 terabytes (TB) of storage on magneto-optical

From the Naval Medical Center, Portsmouth, VA.

The views expressed in this article are those of the authors and do not reflect the official policy or position of the Department of Navy, Department of Defense, or the US Government.

Address reprint requests to Laurence F. Parr, MS, DABR, Department of Radiology, Naval Medical Center Portsmouth, Portsmouth, VA 23708. E-mail: LFParr@mar.med.navy.mil.

This is a US government work. There are no restrictions on its use.

0897-1889/01/1402-1044\$0.00/0

doi:10.1053/jdim.2001.23855

disks (MOD). The intermediate archive storage consists of 380 gigabytes (GB) of serial storage array (SSA) hard drives. The archive is managed by three IBM H50 computers, one as a hot standby, running IBM AIX operating system and BRIT (Dallas, TX) Roentgen Files software. The RIS (QuadRIS by Cerner, Kansas City, MO), a commercial product, runs on two additional H50 computers, with one also a hot standby. In addition to normal RIS functions, the QuadRIS performs critical PACS functions such as tracking the location of studies in the archive, tracking the status of studies, generating worklists used throughout DIN-PACS, and handling study fetching and pre-fetching. Because DoD requires the use of Composite Health Care System (CHCS), the DoD hospital information system (HIS) that already incorporates a RIS, the usefulness and cost effectiveness of the imbedded RIS is limited at this time.

DINPACS includes 77 workstations running Applicare's RadWorks (Zeist, Netherlands) software under Microsoft NT 4.0 (Redmond, WA). The diagnostic workstations use $2,048 \times 2,500$ pixel diagnostic quality monitors each driven by a single Barco (Duluth, GA) Metheus card. The four-monitor diagnostic systems run on an IBM Netfinity 5500 Server with an 18-GB hard disk raid and 384-MB of memory. The two monitor systems use a dual processor IBM MPro PC platform. Review workstations use $1,200 \times 1,600$ pixel monitors driven by a single dual-head Dome (Waltham, MA) video card on a single processor IBM MPro PC. Nine quality-control workstations are dual-processor IBM MPro PCs with 512 MB of memory, a large hard disk raid, and either one or two review quality monitors in black and white or color. Quality-control stations are robustly configured because of the amount of data they must handle.

The network is an ATM network running on fiber optic cable. The network is isolated from the hospital's network and uses two Nortel (Santa Clara, CA) Centillion 1600 ATM switches to move images directly to all workstations using native 155-Mbs ATM. The only connection to the hospital's network is via an OC12 (655 Mbs) line, allowing the hospital PCs to access DINPACS using web or PC software. Web and teleradiology servers are provided to allow the hospital staff and authorized off-site personnel access to DINPACS

resources via internet/intranet and dial-up connections.

Modalities use 10/100-Mbs Ethernet over twisted pair via a Nortel Ethernet switch to connect to DIN-PACS. The modalities are two GE (Milwaukee, WI) magnetic resonance imaging (MRI) units, two GE computed tomography (CT) scanners, five GE ultrasound units, two Siemens (Munich, Germany) angiography units, seven FUJI (Tokyo, Japan) 5000 CRs with DeJarnette (Townson, MD) workstations, and three digital GE Legacy Fluoroscopic units. All are digital and DICOM-compliant to different degrees.

GENERIC DINPACS WORKFLOW

Most radiology patients at NMCP are "walk-in" except in specialty imaging areas. Radiology orders are entered in CHCS and captured by DINPACS via a Health Level 7 (HL7) interface. On arrival in radiology, the patient is "arrived" in CHCS and a message sent to DINPACS via HL7 triggering DINPACS to place the patient on the modality worklists, and pre-fetch and route to the appropriate workstations (up to three) relevant priors. At the modality, the patient is selected from a DICOM modality worklist that provides demographic and study data, including accession number, to populate the DICOM headers. On completion, the study is forwarded to a quality-control workstation, where it is matched to another worklist providing additional data necessary for DINPACS to handle the images. Matching usually occurs automatically, but under some circumstances requires the quality-control technician to perform a manual match. If the study is technically satisfactory, the quality-control technician electronically approves the study, automatically sending it to the archive, the web server, the teleradiology server, and to several diagnostic workstations where it is matched up with relevant priors. Using the accession number, the radiologist dictates the report that a transcriptionist enters into CHCS. This report is then captured by DINPACS via the HL7 interface and stored in the RIS completing the study. This is an overly simplistic discussion and many other essential actions occur throughout the system. Failure of any one of these events can cause from minor to severe problems.

DEPLOYMENT EXPERIENCES

The hospital opened fully digital but not filmless (images were printed on laser film) due to delays in DINPACS deployment. DINPACS installation started in earnest in June 1999 and by November 1999, the system underwent Clinical Utility Determination (CUD) to ascertain its clinical readiness. There was no phased deployment; all of radiology started using DINPACS simultaneously. The most common installation phase problem was that most imaging modality vendors only supported a limited DICOM implementation. These were easily overcome by use of the quality-control workstations that were designed to handle these types of problems. Most other deployment problems were easily and rapidly solved. Once the system was in full use, more serious problems began to appear. These can be loosely divided into user/operator-related problems and hardware/software-related problems. Only the more significant of these will be discussed.

User- and Operator-Related Problems

Training and acceptance by some radiology staff was and remains a nagging problem. The most serious problem group has been the quality-control technicians. Errors by this group cause problems with study routing, study status, study storage, and a number of other lesser problems. An initial investigation of the problem indicated that the quality-control technicians did not consider this activity as an important part of their jobs as radiology technicians. Intensive retraining incorporating didactic and hands-on sessions followed up with competency testing has improved this situation significantly.

The Orthopedic Department has had difficulty in converting to and accepting DINPACS. They require real-time images in each of 15 treatment rooms. With an extreme patient load (300 to 400 patients daily), this has yet to be achieved. There are multiple contributing factors to the problem, of which DINPACS is only one. Patients generally do not arrive early enough to have x-rays completed prior to their appointment. Doctors often request additional images during the appointment. Only two orthopedic radiographic rooms are available to perform 200 to 300 studies a day. Only one orthopedic computed radiography (CR) unit is available and only four DINPACS workstations are located in the clinic. Add to this the time to processes and

distribute images in DINPACS and the compounded problem becomes severe. Because of DINPACS' position in this series of events it receives the blame for the problem. Several actions have been identified to resolve the orthopedic situation: improve patient flow in the clinic requiring early arrival to obtain radiographs; improve use and throughput of the existing xray rooms by converting to digital radiography (DR) or add an additional CR unit in Orthopedics; and deploy a DINPACS workgroup or web server in Orthopedics to rapidly serve up images to PCs located in each treatment room. To date the first has been partially implemented but, due to restricted funding, the latter have not. To that effect, Orthopedics is the only department allowed to print film.

Hardware and Software Problems

The HIS to RIS interface has proven to be a most troublesome area. The DINPACS contract requirements were developed under an expectation that CHCS would be updated to allow bidirectional data transfer. This has not and is not likely to occur. Compounding the problem, CHCS incorporates RIS functionality which DoD facilities are mandated to use. Presently, the DINPACS RIS monitors a unidirectional HL7 port to capture information necessary to execute prefetches, generate worklists, track patients, and capture radiology reports. The requirement to use CHCS without a bidirectional interface nullifies most advantages of integrating a full commercial RIS into DINPACS and prevents the use of the DINPACS RIS as a backup when CHCS is unavailable. Without CHCS, DINPACS workflow essentially stops or is severely compromised. In the event of CHCS/HL7 loss, administrative contingency plans are implemented. The plan requires all images be held at the respective quality-control workstations. If after 30 to 60 minutes CHCS is not restored, studies are manually pushed to radiologist workstations for reading and dictation. The dictation is available on the radiology transcription listen line for clinician access, but cannot be entered into CHCS until it is restored and accession numbers are available. This process generates significant backlogs, the severity of which depends on how long CHCS is unavailable. Deviations from the contingency procedures lead to RIS and Archive database mismatches, lost reports in DINPACS, and study status errors, to name a few. To date, approximately 50% of the

data problems in DINPACS can be related to CHCS availability issues.

Hanging protocols available on diagnostic workstations have been a source of frustration for radiologists. The original concept of hanging protocols called for a simple semiautomated process to perform basic screen set up. Because RadWorks software is capable of far more sophisticated hanging protocols, and due to over-optimism on the part of the radiology staff and the vendor, far more elaborate protocols were developed. These worked in well-defined situations but failed or provided sub-optimal results in normal workday situations. The elaborate protocols relied on certain nonmandatory DICOM data elements being present which were not guaranteed. Additionally, vendor interpretation of radiologist's desires was often inaccurate and radiologist understanding of the system was weak, further exacerbating the problem. This has led to a situation where automatic hanging protocols are marginally useful at best and hinder the radiologist at worst. We are now developing simpler protocols that, after the staff gains a better understanding of the overall system, may be slowly evolved toward more sophisticated and automated protocols.

Automatic fetching of relevant priors can be a time saver for radiologists. DINPACS fetches prior examinations using fields in the Study Table of the RIS database. The most obvious fields used are name, patient identifier, modality, body part, and date of examination. A problem arose when we discovered that the CHCS radiology order did not include "body part," an essential data element for proper selection of prior studies. Although some of the modalities allowed entry of this data at the modality console, this procedure loaded the DICOM image header but not the RIS database field. Also, getting all technicians to use the same nomenclature has been elusive. This inconsistency has led to a situation where many fetched "relevant priors" are inappropriate and many appropriate "relevant priors" studies are not fetched at all. Inconsistent "relevant prior" availability requires the radiologist to use valuable time to do a manual query for the needed studies. To correct this prob-

lem, a program change was instituted to perform a lookup in the RIS Study ID Table, retrieve the body part from that table, and include it in the database record for the study. The Study ID Table is updated any time the CHCS Study ID Table is changed. This has led to some problems due to overwriting of Study ID Table records in DINPACS with incompatible data. Further safeguards are needed.

The original diagnostic monitors showed unacceptable performance and an excessive failure rate early on in the project. After three attempts to correct the problems, all the monitors were replaced with a different vendor's product. Retrospectively, the problem is believed due to delivery of a bad batch of cathode ray tubes (CRTs) by the first vendor's CRT supplier.

The IBM Netfinity 5500s used in the four monitor diagnostic workstations suffer from a severe heat problem due to the four Metheus video cards generating a large amount of heat (>100 watts). The Netfinity 5500 is a server and not designed to manage such heat loads. This situation has led to frequent video card malfunctions, video card failures, several motherboard failures, and anomalies on the monitors related to overheating of the video RAM. After a year of trying various unsuccessful fixes, replacement with appropriately designed computers appears eminent.

CONCLUSION

The DINPACS was designed to digitally integrate and automate DoD radiology at the hospital and regional level. The belief that deployment of this system would be relatively straightforward in a new hospital designed for PACS, and with all imaging modalities purchased with PACS in mind, has proved wrong. Standard problems with training and acceptance of the system remain, as do hardware and software issues. Deployment project officers need to stay fully engaged, taking nothing for granted, and be aware that many problems will not arise until the system is in clinical use since workload and user skills prove to be significant factors in system performance.