

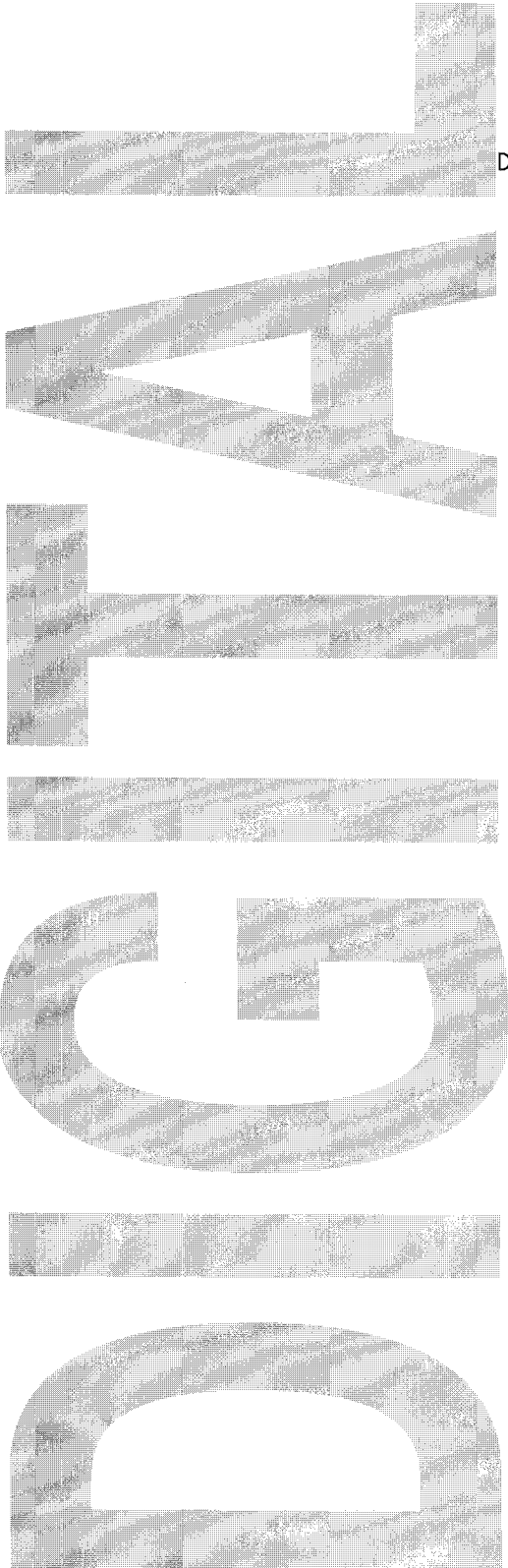
Image Management in High-Volume PACS

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Introduction

..... A growing number of hospitals worldwide are implementing hospital-wide Picture Archiving and Communications System (PACS). A great deal has been written on the advantages, disadvantages and cost-benefits of PACS. The presentation will focus on the highlights of clinical operation using PACS in a new hospital with approximately 380,000 radiological examinations per year, 50% by PACS and the rest by conventional films.

Samsung Medical Center (SMC) is a new tertiary care center with approximately 1050 inpatient beds and a large outpatient clinic facility. The hospital is a 23-story building complex and is located at the southern part of Seoul, Korea. PACS was installed on September 1994 and the hospital opened on October 1994. Outpatient clinics and inpatient wards of orthopedics surgery, neurosurgery, neurology, ER (그림 1), SICU, MICU, PICU and NICU (그림 2) use softcopies only. Although only 14 months into clinical operation using PACS, approximately 1 million images have been archived in PACS. SMC PACS system was originally designed to cover 35% of the hospital's



radiological load but due to the demands of the clinicians for rapid access to images and reports, all of the ICUs exams are read on PACS and workstations installed in ICUs. Although hardcopies are generated, they are not distributed and serve as backup purpose only.

System Overview

The system integrator of SMC PACS is Loral Medical Imaging System. The modalities interfaced to PACS are 3 CR (FCR9000, Fuji), 2 MRI (Signa Advantage 5.4, GE), 2 CT (HiSpeed 1.2, GE), 1 DSA (Advantx, GE), 1 film digitizer (Lumiscan, Lumisys) and 1 laser film printer (KELP 2180, Kodak). Modalities not interfaced yet are 4 CR, 1 DSA, 3 digital fluoro, 3 SPECT, 1 PET and ultrasound mini-PACS. These are planned in the next phase of PACS expansion. Images are temporarily stored on a 40 Gbytes short term storage unit (WSU, Loral) with bit preserving 2:1 compression. Images on the short term storage unit may be accessed rapidly from display workstations, for example, the time required to query, transmit over optical fiber and print one CR image is approximately 2.8 seconds. Because this is a centralized PACS system, the same image may be concurrently accessed by any of the 35 workstations (7 quad-monitors, 15 dual-monitors and 13 single-monitor workstations) on the hospital floors.

Exam verified and read are permanently archived on an optical juke box (ADL 6800, Kodak) with 1

Terabytes capacity. For CR image a non-bit preserving 10:1 compression is performed and for non-CR image a bit preserving compression is performed during archive. For future expansion, 238 horizontal fan-out optical fibers cabling/outlets and 268 unshielded twisted-pair ethernet cabling/outlets were installed during the construction of the hospital.

RIS to PACS

Both the Hospital Information System (HIS) and Radiology Information System (RIS) were designed and developed for SMC by a local company, the Samsung Data System (SDS). The SDS software engineers (47) are currently on-site in the hospital to fine tune the software and to meet new user's requirements. A HIS/RIS to PACS gateway, jointly developed by SDS and Loral, automatically sends new exam requests from HIS to PACS. A RIS/PACS gateway queries new exam orders from RIS database, generates DICOM messages and then transmit to PACS only the OS, NR, NS, ER and ICU requests. Request information includes patient demographic information, procedure and clinical information. Current problem of the RIS/PACS interface is language. Because HIS/RIS system is both Korean/English and PACS only English, the RIS/PACS gateway translates Korean name into English phonetically. We are working on the localization of PACS.

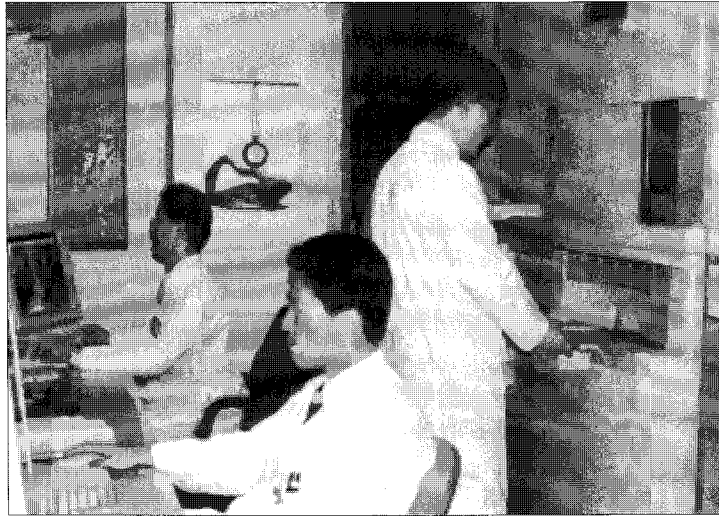


그림 1. A dedicated CR unit (FCR9000, Fuji) and two 2-monitors workstations are installed in ER. ER quality control workstation next to the CR unit is used to process stat exams. Wet readings are done on the radiology floor and ER clinicians access reports/images on ER workstations.



그림 2. Neonatal ICU uses the 2-monitor workstation to rapidly access portable CR images. There is no CR processing unit in the ICU area but as soon as CR plate is scanned on FCR 9000 located on the radiology floor, the image is immediately available on the NICU workstation. When a user

Workload

Since July 1995 (outpatient visits and inpatient admissions were gradually increased since Oct. 1994), the hospital is operating with full inpatient capacity and have approximately 2,300 outpatient visits per day. On average 1,300 radiological exams are performed per day or 32,000 exams per month and so at this rate the department will generate approximately 380,000 exams per year. 50% of these exams are requests from ER (19%), orthopedics surgery (15%), neurosurgery (7%), ICUs (6%) and neurology (3%), and therefore read and archived on PACS. All exams are adjusted for brightness, contrast, position and format by radiographers (그림 3). On any given time, the average number of exams residing on the short term storage unit is 9,500 or 116,000 images. To give a comparison, if this unit is completely filled with MR exams only (100 images/exam), a total of 8,160 exams may be stored.

Daily preparation of the storage unit for new exams includes clearing least accessed exams (in chronological order) until 83% storage capacity is reached. This procedure occurs automatically at 6:00am daily. Of the 100 optical platters (each platter with 10 GB capacity), 37 platters are full with approximately 1 million images.

Fetching Historical Exams

Two different types of fetching are in use for retrieving historical exams from the optical juke box.

The first is the automatic fetch when a new exam is ordered for a patient. For that particular exam, 4 historical exams are retrieved based on modality and exam procedure. For example, if MR brain exam is ordered, then 3 most recent and 1 oldest MR brain exams are fetched automatically. The purpose is of course to have available newly acquired exam as well as historical exams at the time of reading. The fetch starts as soon as a receptionist changes exam status from ordered to arrived. In most cases the time it takes for the patient to finish radiological examination, and when radiologists start their reading sessions, the historical exams are on-line. If the fetch (or retrieve) queue is empty, approximately 1 minute is required to fetch one CR exam. The second type of fetch is the manual ad-hoc fetch.

The problem we faced initially was that outpatient nurses in OS, NR and NS, in preparation for the following day outpatient visits, fetched old exams whenever a workstation is available in the outpatient exam room (그림 4). On average 300 of such exams are requested for fetch and remain in the retrieve queue. In such a case if a radiologist requests a fetch during his reading session or if a clinician wants to review old exams in the optical juke box, they would have to wait several hours before their exams are retrieved. To circumvent this problem, the outpatient nurses agreed to start fetch for the following day clinical visits at 4pm each day. A simple cooperation helped save both radiologist's and clinician's time. Depending on who the user is, different priority of ad-hoc fetch should be established.

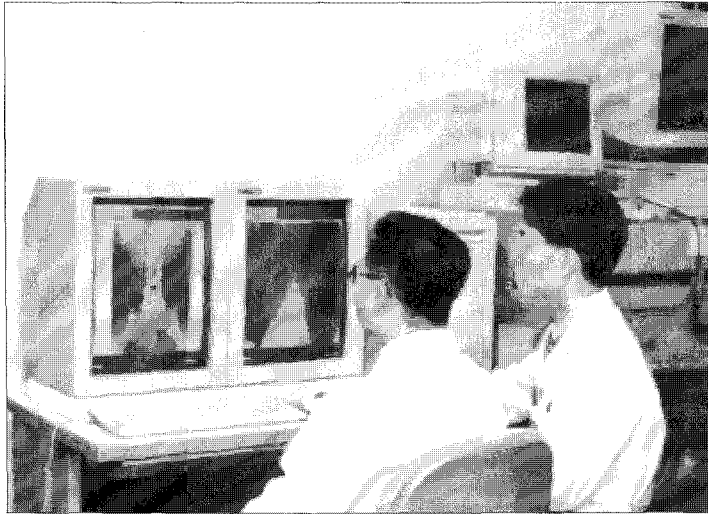


그림 3. All images from MR, CT, DSA and CR undergo quality control and are adjusted for brightness, contrast, position and format before they are available on the unread folders of referring departments. The radiologists save time making unnecessary image modifications when reading such



그림 4. Outpatient nurses at orthopedics surgery, neurosurgery and neurology manually fetch exams of patients for the following day visit. To avoid accumulation of such fetch requests during hospital hours (8:00 am - 5:00 pm) which would make timely (within 5 minutes, say) ad-hoc fetch

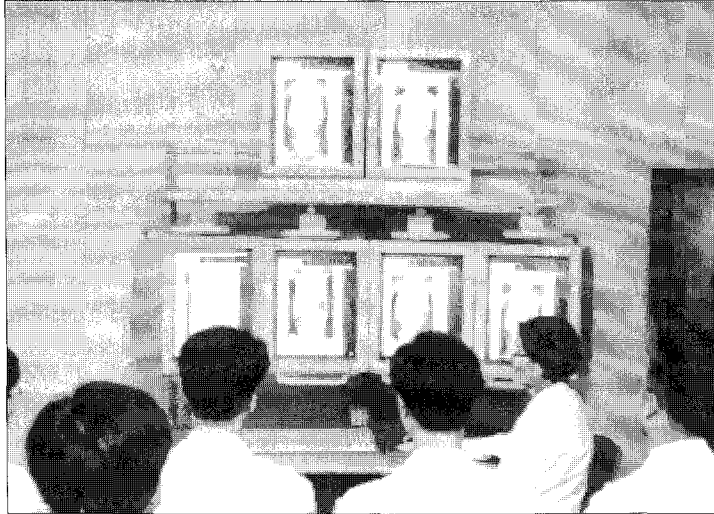


그림 5. A 6-monitors workstation is used daily for conference with the clinicians. The two overhead monitors are slaves to the two of the four monitors underneath and help clinicians at the back row to have an

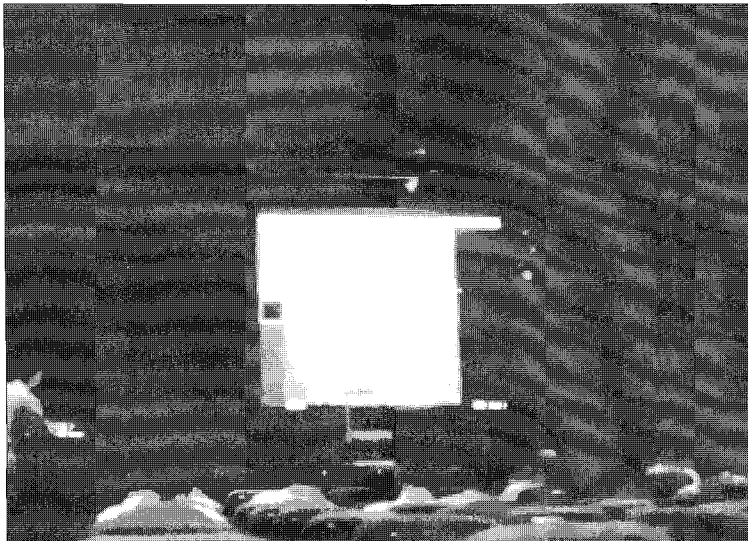


그림 6. A wall beam projector connected to a single monitor workstation and image displayed on a 2.7m by 2.7m screen is used regularly for orthopedics surgery conference as well as for educating new hospital personnel. Cursor actions and real-time image modifications are depicted

Radiologist's Perspective

Radiologists at SMC read exams by referring departments and have daily conferences with clinicians (그림 5 and 6). For example, radiologists-A will read all exams requested by orthopedics surgery and radiologists-B will read neurology/neurosurgery exams. Each radiologists would go into his/her unread folders and commence reading. Fourteen unread folders by referring departments are in use: OS in/outpatient, NS in/outpatient, NR in/outpatient, ER, NICU, PICU, SICU, MICU, nursery, pediatric OS/NS/NR/ER/SICU, and research exams. Standard reports for normal exams are available on the workstations to rapidly complete approved reports using a macro key.

Radiologists read exams by either dictation or direct typing. The diagnostic workstations have been set up so that when a radiologist log-in, the report approval list is presented for report completion. Unread exams remain indefinitely on the short term storage unit until they are read and so the radiologists have to make a conscientious effort to read exams promptly (or the short term storage unit will be swamped with unread exams). Usually 15% of exams remain unread in the first week and completely read before the end of second week. The full cooperation of the radiologists is critical in the successful operation of PACS.

All the radiologists use a macro called the display default protocol (DDP) which is used to display current exam and 3 historical exams on the 4

monitors workstation in a pre-defined order and format. The display time for four CR images is approximately 16 seconds but for MRI exams with approximately 100 images/exam, the display time is approximately 4 minutes although the control of the cursor is available in about 1 minute. Although the display time has been reduced with improvements of hardware and software, there is room for further improvements. The radiologists need to get accustomed to softcopy reading. The radiologists at SMC complained of eye strain and fatigue when PACS was installed. Three to four weeks of adaptation period were required before the complaints gradually reduced. Individual research folders have been created for various radiologists/clinicians and are used daily to accumulate interesting exams for retrospective research. One neuroradiologist has an individual research folder subcategorized into 216 subfolders to classify different tumor types by body part.

Clinician's Perspective

Before PACS was implemented, the clinicians in general were negative in the use of PACS. There were doubts about the response time of the system, resolution and usefulness of soft copies, the quality of images in fully-lit examination rooms, the availability of historical exams and general fear of new technology when forced into their work routine. When PACS was initially introduced at the outpatient clinics, the doctors and nurses would request for films although all exams were readily available on PACS

and kept films aside in case "something" went wrong with PACS. Every efforts have been made to win the confidence of the clinicians and nurses, and provide services as well as support beyond their need. The clinicians soon stopped requesting for films and instead, now demand for more workstations on their floor.

PACS Operation Team

The operation team consists of one Loral on-site engineer, two hospital engineers and three radiographers. Two database engineers monitor the system continually during office hours and access from remote (home) terminal in case of off-hour emergency. They perform weekly database optimization during off-peak hours (3:00 - 4:00am Sunday) to minimize impact on clinical operation. A daily tape backup of the patients transaction log is performed to restore the database in case of catastrophic failure (which has not happened yet). Since PACS is used in ER and ICUs on a 24-hours basis, system down time from preventative maintenance is kept to a minimum and workaround solutions used instead. The hardware engineer regularly calibrate all the CRTs and perform preventative maintenance check on all equipments. In particular, the film digitizer requires weekly cleaning

from static dusts of films.

The three radiographers have diverse roles in the daily operation of PACS. Since they are familiar with the work flow of the conventional film system and obtain daily feedback from colleague radiographers, transcriptionists, file clerks and nurses, they readily recognize potential problems and consult the PACS engineers for remedy. PACS radiographers are also responsible for cancellation of exam orders, merging of exams, digitization of outside and transfer films, and quality control of stat MR and CT studies. They are the first point of contact and manage PACS hot line. Another important responsibility is the education of new radiographers and nurses.

Summary

The clinical implementation and management of a centralized PACS for efficient softcopy operation is presented. Exam requests from OS, NS, NR, ER and ICUs which account for 50% of all radiological exams are read and archived in PACS. PACS is a clinical tool used by the radiologists and clinicians in daily practice, and without their full support and cooperation, PACS would indeed be impossible to manage.