Digital Radiology at the University of California, Los Angeles: A Feasibility Study

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This paper describes a set of feasibility studies on converting the Department of Radiological Sciences, UCLA from a film based operation to a digital based operation. The studies address the following topics: the departmental facility, the operating procedure and cost, a cost effective analysis and a proposed digital based operating system. In addition, we examine three prototype projects being carried out in our department. These include: a digital archiving and communication system, a hybrid archiving and communication system, and a multiple image viewing system.

INTRODUCTION

THE CONCEPT OF A DIGITAL OR ELECTRONIC RADIOLOGY DEPARTMENT was discussed as early as 1973. However the technology present at that time did not make its construction feasible. Now, with the increasing numbers of digital based diagnostic modalities, the maturity of the field of computer based hospital management, and the progress in digital electronics and communication systems, it is necessary to realize this concept.

The purpose of this paper is to summarize a study on the feasibility of converting our department into a digital department. A digital radiology department consists of two components; a radiology information management system and a digital image system. The radiology information management system represents a problem in data base management which has been addressed repeatedly in the past few years and will not be considered in this study. Development of a digital image system requires the technology of image acquisition from various diagnostic modalities, as well as the develop-

ment of systems of image archiving, communication, display, and manipulation. Moreover the economic aspect must also be considered. In the past some studies along this line have been performed and the indications favor a digital based approach.^{2,3} In this study we organize the analysis into four parts:

- a. *Facility study.* This part details an inventory of the existing major diagnostic equipment and the equipment to be added in the next two years as well as their distribution in the department.
- b. *Operating procedure and cost.* The daily and the monthly operating procedure in our department is reviewed. A post three-year cost breakdown is then given on staff FTE (full-time-equivalent), maintenance, operation, film, and storage.
- c. *Cost effective analysis.* A cost effective analysis on converting our department into digital is given.
- d. *A digital based operating system.* Several possible systems for converting our department into digital are considered. We also describe three ongoing prototype subsystems being investigated.

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Fig 1. Organization chart for the Department of Radiological Sciences, UCLA.

FACILITY STUDY

1. The Department of Radiological Sciences

The UCLA Medical Center is a 685 licensed bed teaching hospital, and the Department of Radiological Sciences occupies about 80,000 square feet of space. The Department is composed of four divisions: Diagnostic, Nuclear Medicine, Biophysics, and Medical Physics. The Division of Diagnostic Radiology is patient-oriented and is decentralized into ten operationally independent sections: Neuroradiology, Emergency, Pediatric, Mammography, Chest, Musculoskeletal, Cardiovascular, Genitourinary, Ultrasound and Body CT, and Gastrointestinal. The Nuclear Medicine Division is also patient-oriented and together with the Division of Biophysics monitors one of the largest PET (Positron Emission Tomography) research programs in the nation. The Division of Medical Physics provides the scientific and technical resources for the Department and offers M.S. and Ph.D. degrees. This division also operates a dedicated image processing laboratory. Figure 1 depicts the structure of the department.

2. Major Diagnostic Equipment

An inventory on major diagnostic equipment in our department reveals the following:

2.1 Existing Equipment

- 1 Fonar QED 83000—3 kgauss permanent magnet whole body NMR scanner (being installed).
- 2 CT Scanners 1 GE 8800 (3rd generation) 1 Technicare 1440 (4th generation)
- 2 PET Scanners 1 Neuro ECAT—Positron Emission Tomographic brain scanner (Ortec) 1 Ecat III—Positron Emission Tomographic body scanner (Ortec)
- 7 Ultrasound units
- Digital fluoroscopic unit 1 Philips OVI connected to an angiographic unit 1 ISOCON connected to the GU fluoroscopic unit 1 ADAC DPS-4100S with two cameras and an imaging network processing station connected to a neuro fluoroscopic unit and an angiographic unit
- 1 ADAC-PDX-4800 Projection Digital X-ray System
- 1 Mammographic unit
- 6 Special procedures application x-ray systems

2.2 Equipment Being Ordered

- 1 Technicare 5-6 Superconducting magnet whole body NMR scanner
 - 1 Technicare Digital radiography system (DR 960-B) connected to an angiographic unit
 - 1 Prototype slit scanning digital chest system
- Figure 2 shows the relative location of this equipment in the department.

Fig 2. Location of diagnostic equipment, the Image Processing Laboratory, and the communication network.

OPERATING PROCEDURE AND COST

Conventional diagnostic images obtained from either x-ray or other energy sources are recorded on films. These films are viewed from illuminated viewboxes and later stored in the film library for future use. Diagnostic images

obtained from digital acquisition systems, for example, nuclear medicine, digital ultrasound, transmission and emission tomography, digital radiography, and nuclear magnetic resonance, are first displayed on TV monitors for immediate viewing and then recorded on magnetic tapes or disks for archiving. In addition, they are also recorded on films as a permanent record and for future viewing. Since films are convenient to use in a clinical setting, clinicians prefer to view these digital images as films even though this reduces image quality. As a result, our department still has to handle films from all diagnostic modalities without regard to their conventional or digital origin. Because of this, we investigate the costs for this film based operation. Table 1 is a three year estimate on the number of procedures and film usage in the ten diagnostic sections and the nuclear medicine division. Table 2 shows the three year estimate of the film and film related costs in our department.

In compiling these tables, we include negative preservers, x-ray film jackets, x-ray mailing envelopes, x-ray insert envelopes, rental on film storage, fleet services for film delivery, and miscellaneous supplies such as the film library coats, and film processor purchases, film solutions, replacement parts, facilities repairs and installations and other miscellaneous supplies as the film processor costs. As indicated in the tables, each year we perform about 113,000 procedures and use about 500,000 sheets of film. This film based operation costs about 1.5

Table 1. Three Year Estimate on Number of Procedures and Film Usage

Section	Number of Procedures			Film (Sheets)			Film (Cost)		
	79-80	80-81	81-82	79-80	80-81	81-82	79-80	80-81	81-82
Nuc Med				13,500	11,500	11,100	\$16,205	\$14,321	\$12,474
GU	4,382	3,849	4,007	34,500	31,875	31,075	41,656	48,269	47,158
Peds	8,873	8,447	8,041	41,850	33,650	38,250	52,198	54,003	65,431
GI	5,359	4,990	4,984	64,700	61,100	54,700	78,588	88,120	75,544
Neuro&CT-H	4,470	4,457	4,747	24,900	21,500	28,100	29,076	32,250	40,006
US&CT-B	7,227	8,222	8,293	25,100	35,400	34,300	28,972	31,271	32,818
Cardio	837	910	1,396	25,750	26,000	27,050	42,641	50,148	46,353
General OPD	19,637	18,269	21,890	124,725	96,950	96,950	155,841	173,267	164,568
General IP	39,810	41,432	35,573	106,215	99,330	95,800	143,650	182,770	154,985
Mammography	921	1,152	1,257	4,500	7,600	8,100	4,194	6,992	6,890
Emergency	26,296	23,911	22,884	74,000	80,100	78,900	94,287	128,579	120,042
TOTAL	117,812	115,639	113,072	539,740	505,005	504,325	\$687,308	\$809,990	\$766,269

Table 2. Three Year Estimate of Film and Film Related Costs

	1979/1980	1980/1981	1981/1982
Film Library	49,350	51,623	45,577
Indirect Expenses	25,823	30,251	25,204
Film Processor	60,674	58,518	86,809
Indirect Expenses	28,867	26,991	26,239
Personnel:			
Darkroom	135,012* (3.8)**	155,832 (9.1)	171,488 (9.8)
Film Library	371,199 (25.2)	388,608 (25)	432,524 (24.3)
Film-related Cost			
Total	670,925	711,823	787,841
Film	687,308	809,990	766,269
Total Costs	\$1,358,233	\$1,521,813	\$1,554,110

*Salary and fringe benefits.

**Full time equivalent (FTE).

million, about half of it is for films and the other half for film related costs. This operation requires about 34 FTE of which 70% is dedicated to the film library. The film operation requires approximately 2,600 square feet of space within the department and an additional 10,000 square feet for film storage in a satellite location. By performing this type analysis, we hope to be able to estimate the increased or decreased costs associated with a digital based operation.

COST EFFECTIVE ANALYSIS

Based on our study on operating procedure and cost we come up with a ten-year cost projections for a conventional film based and a digital based operation in our department. Table 3 shows these estimates.

It is seen from this comparison that we would be able to save about four million over a ten year span, of about 400,000/year. Two major factors contributing to the savings are the reduction in

Table 3. Ten Year Projection and Cost Comparison Between a Film Based Operation and a Digital Based Operation*

Film Based Operation	In Thousands	Digital Based Operation	In Thousands
Film	7,000	Replace conventional chest to digital chest	
H ₂ O for the processors (60 M gallon @ 10.0/1000 gallon)	600	Six units @ 500,000	3,000
FTE (34) [†]	7,000	Image memory	1,000
Processor	1,000	TV monitors 1000 unit	1,000
Film storage rental	500	Terminals 200 unit	2,000
Matrix camera purchase	500	Analog/Digital storage	1,000
Space (equivalent cost)	2,350	Communication network	1,000
Physicians time lost (\$10/hr)	1,500		
Equipment (x-ray)	2,000	Sub Total	9,000
		Maintenance 10%/year for ten years of equipment cost (9,000)	
		We take half of this value.	4,500
		FTE (15) [†]	3,000
		Sub Total	16,500
		10% of film based operation**	2,250
Total	22,450	Total	18,750

*Excluding digital based equipment purchase.

**We believe films are still necessary in a digital based operation.

[†]We anticipate the FTE qualifications will be the same in both operations.

Fig 3. A general digital based radiology department operating system.

film cost and reduction in FTE positions. We agree that these cost estimates are not exhaustive and are certainly subject to challenge, especially when estimating the digital based operation. Nevertheless we believe the amount of saving is genuine. Moreover, there are benefits in a digital based operation which we cannot translate directly to the dollar amount. These include ease of record keeping, no loss of image information, and a savings in record retrieval time.

A DIGITAL BASED OPERATING SYSTEM

With all of these advantages in a digital based operation, we have decided to perform some preliminary studies on how to change our department from a film based operation to a digital based operation. At the present time we perceive that a digital based operation requires the components shown in Figure 3. We will not discuss the technical aspect of these components since they have been discussed elsewhere. Instead we will consider the possible combination of these components in such an operation.

A. Image Acquisition

Image acquisition is a component already in existence. It can arise from either a conventional or a digital diagnostic modality. We anticipate the former modality will contribute less and less as we move further towards digital.

B. Image Archiving System

An image archiving system has three components, an image storage device, a mechanism of transmitting images from diagnostic modalities to the storage device, and a means of image retrieval.

For digital based modalities, the storage device can be a very large magnetic disk system, an optical disk system, or a digital coded fiche. The mechanism of transmitting images could be through a digital communication line or a digital/video broadband communication system from the modality to the storage device.

For conventional x-ray films, the mechanism of transmitting images could be a digitizer converting the analog image to digital form and a communication system which transmits the digital information to the storage device. A less acceptable method is to reduce the x-ray films and store them on microfiche. In this case, the image storage device would be a hybrid system. The retrieval mechanism is necessary for sending the stored images to the proper viewing site. It is relatively straightforward in a digital storage device based system but not so simple for a hybrid system.

C. Image Viewing System

The image viewing system is for displaying multiple diagnostic images from the storage

device. This system requires a very large image memory, a video output control, a powerful image processor, and a bank of viewing monitors.

D. Image Communication System

The image communication system is for distributing the images from the viewing system to various locations within the department. The image viewing system, together with the communication system would replace the conventional x-ray film reading room.

PROTOTYPE SYSTEMS UNDER INVESTIGATION

Currently we are investigating three prototype subsystems: two for picture archiving and communication and one for image viewing.

A. A Digital Archiving and Communication System

A communication and archiving system based on the Ethernet communications protocol has been designed and is under installation. The preliminary communication network will connect our dedicated Image Processing Laboratory in the department to two digital fluoroscopic units, a projection digital x-ray unit, and a CT body unit. This communication system is relatively slow and will take from two to four seconds to transmit a $512 \times 512 \times 8$ diagnostic image. A parallel system using the broadband communication system which combines both digital and video communication is being designed. This system can communicate diagnostic images in real time.

B. A Hybrid Archiving and Communication System

We are collaborating with a manufacturer to design a hybrid archiving and communication system based on microfiche. Images are recorded on microfiche either in analog or in digital coded form. The microfiche is stored in a carousel for automatic retrieval. Analog images can be viewed through an optical reader and digital images can be transmitted to a proper

digital diagnostic console and viewed from the display monitor.

C. Multiple Image Viewing System

A four phase research project involving the installation of multiple digital image viewing stations in our department is being implemented. Each viewing station will be able to display and manipulate up to six 512×512 radiographic images simultaneously. The four phases of this project are: (1) simulation of a digital viewing station at the Image Processing Laboratory, (2) installation of a viewing station at a remote diagnostic section, (3) installation of a second mobile viewing station, and (4) an evaluation of the entire project. The first phase of this project has already been completed.

SUMMARY

We have described a feasibility study on converting our department from a film based operation to a digital based operation. In the next few years we perceive that all major diagnostic equipment in our department will be digital based with the exception of conventional chest units. It is therefore our goal to look into the possibility of changing our operation from film based to digital based. The two major cost factors in a film based operation are the films and FTE positions. A digital based operation can keep these two cost factors to a minimum. In addition, a digital based operation has the advantage of having better record keeping, better image information retention, and amount to a substantial savings in handling time. However, there is an unknown psychological factor which is difficult to assess at the moment. Namely, would a digital based operation be acceptable by physicians. In order to investigate this aspect we are in the process of studying three prototype subsystems. By developing these prototypes in a clinical environment we hope to assess the feasibility of fully implementing a digital based radiology department.

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