MEDINFO 2001
V. Patel et al. (Eds)
Amsterdam: IOS Press

Economic Analysis of a Filmless System Based on the Hospital Information System

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Abstract

A filmless system (FLS) based on a picture archiving and communication system (PACS) equipped with UNIX workstations and a local area network (LAN) specialized for viewing radiographs has not been deemed acceptable, for reasons of economics. However, personal computers (PCs) have recently become more powerful, to the point where PCs approach UNIX workstations in terms of capabilities. As a result, a PC-based image viewing workstation (IVW) has sufficient functions for practical use. Diagnostic resolution is not equal to that of film, but is comparable. Since the hospital information system (HIS) includes many PC terminals connected by a LAN, the cost problem can be resolved by using these PC terminals as the IVWs. In order to investigate the practicability of this idea, two types of FLSs using HIS facilities were designed: one is a system based on the use of high-resolution cathode ray tubes (H-CRTs), and the other is based on the use of conventional CRTs and radiologist reports, minimizing the number of H-CRTs. The total costs of the two systems were analyzed. As a result, the former FLS was found to be about 15% more expensive than the latter, which was less expensive than a film-based system (FBS). However, whether the FLS is more profitable than the FBS from the viewpoint of hospital management strongly depends on the medical insurance system.

Keywords:

Economics; Radiology information system; Hospital-wide PACS; Filmless; Hospital information system

Introduction

Many studies have pointed out the effectiveness of PACS [1-3], and PACS has been recently installed in large hospitals and medical centers. However, installation has been limited to the radiology department or to special sections such as the intensive care unit (ICU) or the emergency room, due to the high costs for PACS construction. Two recent studies of the cost-effectiveness of PACS in the radiology department and ICU reported that PACS was not yet able to reduce the cost of image management [4,5]. However, these results do not directly indicate that a hospital-wide PACS is less economical than a film-based system (FBS); if a filmless system (FLS) could be realized, the cost of all equipment related to film could be largely eliminated and the cost of PACS per exam would become lower than for a department-wide PACS.

When a PACS is expanded, the increase in cost comes from increases in the number of IVWs and the storage capacity and communications capacity of the network [6]. In the latter half of the 1990s, the capabilities of PCs improved rapidly and became sufficiently high for manipulation of medical images. Although the resolution of a conventional CRT of a PC was 1024x768 pixels and 8-bit gray scale, this was sufficient for diagnosis on the basis of computed tomography (CT) images and for referring to other types of images, such as magnetic resonance imaging (MRI) or computed radiography (CR) images [7]. Parasyn et al. have pointed out that, for diagnosis purposes, a PACS diagnostic workstation and a PC-based IVW [8] show no statistically significant difference. Since the resolution of a CRT on the latest PC can be set up to 1600x1280 pixels, PCs can be used as a main IVW in the FLS. Meanwhile, the communications capacity of LAN has also improved considerably, and the cost of LAN construction has dropped. Therefore, in upgrading an HIS, old PC terminals

and a low speed LAN are replaced by new, more powerful PCs and a high speed LAN, such as ATM LAN or Fast Ethernet. Under these circumstances, constructing an FLS from HIS facilities is a natural idea; that is, PC terminals are used as IVWs and the LAN for the HIS is used as the networking infrastructure for delivering images.

In Kochi Medical School Hospital, a hospital-wide PACS using HIS PC terminals as IVWs was developed in 1997 and has been used by physicians for referring to CT, MRI, and CR images in out-clinics and wards [9]. The system includes about 240 PC-based IVWs. The frequency of image access by PC-based IVWs has continually increased, and at present ranges from eighty to one hundred times per day. As a natural extension of this effort, we designed two types of FLSs from HIS facilities, taking account of the conditions required by our physicians. We estimated the construction cost of these FLSs, taking into account hospital size, and evaluated the economics of an HIS-based FLS as compared with an FBS (film-based system).

Methodology

First, in order to determine the equipment requirements and the functionality of an HIS-based FLS, we solicited the opinions of our physicians who often used our PC-based PACS, with regard to introduction of an FLS, focusing on their concerns and requirements. Taking these results into account, we determined the number of display devices constituted by PC-based IVWs, the number of PC-based IVWs equipped with high-resolution CRTs (H-CRTs), the data volume of the image database servers, and other design parameters.

Second, in order to take into account the scale of a hospital, we created model hospitals whose capacities ranged from one hundred beds to one thousand beds. Based on data for Japanese hospitals published by the Japanese Ministry of Health and Welfare [10] and in a journal [11], we determined the average number of outpatients, the number of radiograph devices, and the number of PC terminals corresponding to the number of beds. From our own hospital's statistical data regarding number of radiographical exams, for each model hospital we estimated the data volume of produced digital images.

Third, we estimated the construction and running costs of FLSs for model hospitals and investigated the cost difference between two types of HIS-based FLSs: one is a system based on the use of H-CRTs, and the other is based on the use of the conventional CRTs and radiologist's reports, minimizing the number of H-CRTs. Finally, we evaluated the total costs of the two HIS-based FLSs and compared these with the total cost of an FBS.

Design of an HIS-based FLS

Physician Requirements

Via questionnaires, we solicited the opinions of fifty physicians who use our PC-based IVW more than twice per week, with regard to introduction of an FLS. We obtained thirty-four replies. Of these, twenty-two physicians (64.7%) consent to the introduction of an FLS, on condition that it is more economical than the present FBS, and two physicians (5.9%) oppose the introduction of an FLS. Four physicians (11.8%) support introduction and five physicians (14.7%) are agreeable, on condition that CRT images are of the same quality as films. One physician did not present his opinion. Twenty-nine physicians (85.3%) expressed concern about use of an FLS leading to erroneous diagnosis. The physicians also worry about the reliability of the system (41.2%), reduction in performance of image viewing (38.2%), and restrictions on places to view images (29.4%). We infer that these anxieties stem from the physicians' experiences of using PC-based IVWs. As pointed out in our previous paper [9], using PC terminals as

Table 1 - Physician requirements for equipment of a filmless system (FLS)

A: Necessity for a PC-based IVW equipped with an H-CRT in an out-clinic				
No	**Yes**			
	1 or 2 per clinic		**one in each consultation room**	
25.0%	31.3%		43.8%	
B: Necessity for a PC-based IVW equipped with an H-CRT in a ward				
No	**Yes**			
	1 or 2 per ward		**3 or 4 per ward**	
12.6%	65.6%		21.9%	
C: Number of display devices attached to a PC-based IVW in out-clinics				
one	**two**	**three**	**four**	**> 5**
47.1%	32.4%	11.8%	5.9%	2.9%
D: Number of display devices attached to a PC-based IVW in wards				
one	**two**	**three**	**four**	**> 5**
38.2%	26.5%	17.6%	14.7%	2.9%
E: Retention period of images stored in servers for fast access				
3 months	**6 months**	**1 year**	**3 years**	**5 years**
29.4%	35.3%	17.6%	14.7%	2.9%

IVWs introduces three problems: spatial resolution, the range of gray scale, and comparison among different exams.

In Table 1 we show physician requirements with regard to equipment of an FLS. In connection with the fear of making erroneous diagnosis, many physicians require equipping a PC-based IVW with an H-CRT for medical use: 2k×2k pixels and 10-bit gray scale. In Japan, CR images are usually read by physicians themselves, whereas CT and MRI images are mainly read by radiologists. These practices also explain the requirement for many H-CRTs.

System Design

The key point of physicians' requirements is the quality of images on a CRT. Our previous study shows that image access speed is also crucial. These requirements are apparently satisfied by equipping all PC-based IVWs with H-CRTs for medical use and by storing image data on the hard disk of a server for three years. However, such equipment is not acceptable from the economical viewpoint. Our main task is to determine reasonable equipment from the clinical, practical, and economical viewpoints.

In order to investigate clinical differences between Fuji Computed Radiography (FCR) images printed on film and those displayed on a CRT with 1024x768 pixels and 8-bit gray scale, we recently carried out ROC (receiver operating characteristic) analysis for pneumothorax cases. The results show that no statistically significant difference exists between diagnosis by film and that by CRT. Since this study used an original spatial resolution of CR images of 2100x1700 pixels, only 25 % of a full image was displayed on a CRT and the operation of viewing images on a CRT was somewhat difficult. Such an operational problem will become less serious with the adaptation of spatial

Table 2 - Facilities in model hospitals

beds	outpatients /day	consultation rooms at out-clinics	doctor lounges	conference rooms	operating rooms	ICU beds	CT devices	MRI devices	other digital devices	PC terminals
100	149	7	2	2	2	1	1	1	1	40
200	290	14	4	3	3	2	1	1	2	65
300	432	22	6	4	5	3	1	1	3	89
400	574	29	8	6	7	4	2	1	4	114
500	716	36	10	7	8	5	2	1	5	139
600	858	43	12	8	10	6	2	2	6	163
700	999	50	14	10	12	7	2	2	7	188
800	1,141	57	16	11	13	8	2	2	8	212
900	1,283	64	18	12	15	9	2	2	9	237
1,000	1,425	71	20	14	17	10	2	2	10	262

Table 3 - The volume of radiographical exams in model hospitals

beds	No. of CT exams / year	No. of MR exams /years	No. of other exams/year	CT films/year	MR films/year	other radiographical exams films/year	total data volume/year* (GB/year)
100	1,420	660	6,550	4,540	4,110	16,700	238
200	2,800	1,300	12,920	8,960	8,100	32,950	470
300	4,190	1,940	19,310	13,410	12,090	49,240	702
400	5,580	2,590	25,700	17,860	16,140	65,540	935
500	6,970	3,230	32,100	22,300	20,120	81,860	1,167
600	8,350	3,870	38,490	26,720	24,110	98,150	1,399
700	9,730	4,510	44,860	31,140	28,100	114,390	1,631
800	11,120	5,160	51,260	35,580	32,150	130,710	1,864
900	12,510	5,800	57,650	40,030	36,130	147,010	2,096
1,000	13,900	6,440	64,040	44,480	40,120	163,300	2,329

* Each CT or MR film contains 12 images of 512x512 (pixels)x2 (bytes). Other films contain 1.1 images of 2000x2500(pixels)x2(bytes).

resolution of 1600x1200 pixels on a recent, powerful PC. In that case, H-CRTs for medical use might be unnecessary, except for very delicate diagnosis from CR images of lungs and bone. Therefore, we consider two alternatives as measures to address the anxieties of physicians and to ensure reliable diagnosis by CRT images. One is to serve reports of all breast CR tests to physicians by additionally employing part-time radiologists, minimizing IVWs equipped with H-CRTs (IVW-Hs) at out-clinics and wards. That is, the IVW-Hs are installed only in consultation rooms of respiratory and orthopedics clinics, and in conference rooms at wards and central divisions. The other measure is to install an IVW-H in each consultation room, each doctor lounge, and each conference room.

Although images of two studies can be displayed on a CRT simultaneously by use of multi-windows technology, the operations for comparing images of one study with those of another study are rather complicated. Therefor, all IVWs in consultation rooms and wards are designed to be equipped with two CRTs, and IVWs in conference rooms are designed to be equipped with four CRTs.

The number of IVWs in wards, out-clinics, and central divisions were assigned as follows, on the basis of physicians' requirement and our collective experience. An IVW is installed in each consultation room in out-clinics, in each conference room in wards and central divisions, in each radiographical exam room, in each operating room, and at each ICU bedside. Two IVWs are installed in each doctor lounge in wards. Since an H-CRT and a conventional CRT are not controlled by a single PC, an additional IVW is needed for installing the H-CRT. At the radiology center, we additionally need diagnostic IVWs for radiologists making diagnostic reports. We estimate the number of diagnostic IVWs from the number of radiographical exams.

Since the cost of storage devices for the database server is greater than that for an MO (magnetic optical) disk library system, only new image data are stored in the database server. Taking into account physicians' requirements (Table 1E), here we considered two database server systems of different storage volumes: one can store half year's worth of radiographical exams, and the other can store one year's worth. The capacity of an MO disk library system was determined as five years' worth of radiographical exams, because Japanese law requires that data of exams be archived for at least this length of time.

Model Hospitals

In order to take into account scale of a hospital, we created model hospitals, based on published information concerning Japanese hospitals. We considered hospitals having capacities ranging from one hundred beds to one thousand beds. We determined the facilities of model hospitals as shown in Table 2, in order to determine the equipment of the FLSs. Since the other digital devices in Table 2 are mainly FCR devices, we estimated the number of X-ray exam devices to be three times the figures given. The numbers of radiographical exams in a year were calculated on the basis of data from our hospital, which has 600 beds. The numbers of exams, films, and data volume are presented in Table 3.

Cost Analysis

In the cost analysis we evaluated the costs of H-CRTs, additional PCs, additional conventional CRTs and multi-display adapters for IVWs equipped with the multi-CRTs, the image database server, and the MO disk library system. The additional PCs are needed for control of the H-CRTs and the installation of IVWs in conference rooms, operating rooms, radiographical exam rooms, and at ICU bedsides. We also evaluated the cost of hardware maintenance. In the FLS minimizing the number of H-CRTs by radiologist's reports, we evaluated the cost of employing part-time radiologists to diagnose breast CR images, whose volume was estimated to be one-third of other exams in Table 3.

Since hardware of an information system is usually replaced each five years, we calculated the costs of all hardware related to the FLS and maintenance cost over five years. The prices of hardware were assigned as follows, based on the Japanese market: 4kUS$ / (additional PC including LAN connection), 3kUS$ / (image viewer software), 400US$ / (conventional CRT), 1kUS$ / (multi-display adapter), 20kUS$ / H-CRT, 100kUS$ / (diagnostic IVW for radiologist), 15kUS$ / (gateway to connect a radiographical device with LAN of HIS), 130kUS$ / (an image database server of 150GB storage capacity), 140kUS$ / (an MO library system of 900GB storage capacity), and 80kUS$ / (an MO library system 250GB storage capacity). In addition to the cost of hardware, we estimated the cost for installation of the system at 10% of the total cost of hardware. The cost of maintenance per year was also estimated at 10% of the total cost of hardware. One hour's labor of a part-time radiologist was estimated at 60US$.

Since an H-CRT for medical use is very expensive (estimated at 20kUS$), the total cost of the FLS based on the IVW-H use is about 15% more than that of the FLS minimizing the number of H-CRTs. However, if the price

Table 4 Comparison of five-years costs between the FBS and the FLS minimizing the number of H-CRTs

Beds	Total cost in the FBS (kUS$)	Total cost in the FLS (kUS$)	Difference (kUS$)
100	1,267	1,032	235
200	1,876	1,565	311
300	2,621	2,048	573
400	3,281	2,845	436
500	3,996	3,412	584
600	4,506	3,869	637
700	5,249	4,521	728
800	5,909	5,063	846
900	6,624	5,662	962
1,000	7,264	6,362	902

of a H-CRT decreases by 50%, the costs will become almost equal. If we use 1/10 irreversible compression for storing image data, we can reduce the total cost by 10% to 18%. When the retention period of the image data in the database server is reduced from one year to a half year, the total cost decreases by 2% to 8% for reversible compression storage.

The cost of the FLS minimizing the number of H-CRTs and storing half year's worth of exams in the database server using reversible compression storage was compared with that of the FBS. In the estimation of the cost for the FBS, we took into account the following items: films, film bags, personnel for film management, the film filing system, laser printers, film processors, light boxes, and disposal of films and developer. The total costs of the FBS and the FLS are presented in Table 4. In the pure cost-based comparison, the FLS is more economical than the FBS. However, the cost of films is paid from the medical insurance in Japan. When this payment is taken into account, the FBS is more profitable from the viewpoint of hospital management. This is caused by that the cost of the FLS is not suitably accounted in the present Japanese medical insurance system. If a portion of the cost in the FLS, for example about half cost of films in the FBS, is paid from the medical insurance, the FLS is as profitable as the FBS.

Conclusions

The economics of two types of HIS-based FLSs were investigated. One of the FLSs designed herein was more economical than an FBS in terms of pure cost analysis. However, whether that FLS is more profitable than the FBS from the viewpoint of hospital management strongly depends on the medical insurance system. If a portion of the cost in the FLS is supported in the medical insurance system, the HIS-based FLS should be practical.

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