Integration of medical images into the total hospital information system– Experiences at Kochi Medical School


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Abstract
Since 1989, the integration of medical images into the total hospital information system (HIS) at Kochi Medical School has been investigated. The developed system was put into practice in August 1997 after a test run was conducted between October 1995 and July 1997. The basic concept of the integration is that doctors can retrieve and view images same as the textual data of lab exams on the desktop personal computers (PC) used to operate the total HIS. During the realization process of the integration we found that several conditions should be satisfied in order to make the integrated system effective and attractive for doctors. Particular attention was paid to the processing time required to acquire images from the image database system using the image viewing station. The image access time should be at least less than a half minute. After making various improvements, very fast image accessing was realized. However, the final system still has three problems: quality of the image display, operation of multi-exams and quality assurance of the digital image.

1. Introduction

In the 1990 years, total hospital information systems (HISs) have been installed in many large-scale hospitals. Total HISs consist of a medical affairs system, an order-entry system, a retrieval system and several subdivision systems. These systems allow doctors via a system terminal to retrieve lab exam results and drug history very quickly. However, in addition to filling out patients’ medical records, doctors have to input order-entries for lab exams and prescriptions by using keyboards. Furthermore, medical images as radiographs and endoscopy results are served to them in the film or photograph. As a result, the implementation of the total HIS enhanced scattering the information required by doctors and made doctors’ work more complicated. An electronic medical record system, which is currently being intensively investigated in the world [1], may be one of the most reasonable solutions to this problem. However, integrating textual medical information alone into the electronic medical record system is insufficient. A total HIS as well as medical images, which are vital to medical decision making, should also be integrated into the electronic medical record system.

In Japan, the first total HIS called the Integrated Medical Information System (IMIS) was established at Kochi Medical School in 1981[2]. At the end of the 1980’s, when the concept of an electronic medical record system was not well defined, we began investigating the integration of medical images into the IMIS for the reasons mentioned above. At that time, specialized workstations were usually required for viewing medical images [3,4]. However, a separate total HIS terminal and image viewing station reduces usability [5], increases costs and requires more physical space. Therefore our aim was to integrate images into the IMIS so that images could be retrieved and viewed on the terminal personal computers (PCs) used to operate the IMIS [6]. After long preliminary use of a prototype system, in October 1995 we began a test run of the system in a clinical setting. Based on the evaluation of the test run the prototype system was improved and a renewed system was introduced in August 1997.

During system development, fast access to images was found to be more important than being able to access images from anywhere in the hospital, although
the latter is certainly an important condition. Several minutes waiting to access images caused doctors to avoid using the image viewing function. The importance of image access speed was also pointed out by Seshadri et al. [7].

After achieving fast image access, the image viewing function is now used on a daily basis in a clinical setting. However, in order to make the integration of medical images into a total HIS more effective and eventually go to the film-less and photograph-less stage there are still several problems to be overcome including: quality of the image display [5,8], operation of multi-exams [9] and quality assurance of the digital image [10]. The first two problems are due to hardware limitations such as, the ability of standard PCs and cathode ray tubes (CRTs). Therefore due to the current rate of technological improvement, we expect these problems to be solved in the near future. Although the third problem exists in the conventional system, it is made more serious by the present integration, which enables doctors to access images within a few minutes after the completion of each exam. We have to establish the quality assurance system as early as possible.

In this paper we present an explanation of the concept of integrating medical images into a total HIS in section 2, an evaluation of the test run in section 3, a description and evaluation of the improved system in section 4 and a discussion of our findings in section 5.

2. The concept of integrating medical images into a total HIS

A total HIS allows doctors to obtain various text based patient data from the terminal PCs of the total HIS. It is also extremely useful for doctors if, in addition to this text based data, they were able to view medical images such as, computed radiography (CR), computed tomography (CT), ultrasound (US) exams and endoscopic (ES) images, on the same terminal PCs. Thus, after considering usability and economy the following six conditions for integrating medical images into a total HIS were arrived at:

- The image retrieval function should be added to the operation screen of the total HIS.
- The operation screens of the image viewer and the total HIS can be easily switched between.
- The image quality on the CRT should be high enough to allow reference and tentative diagnosis.
- The processing time to retrieve images from the image database system (IDS) is less than a few minutes.
- The latest image information should be made available to doctors as early as possible.
- A standard PC should be used as an image viewing station.

![Operation flowchart of retrieving and viewing images.](image)

**Fig.1 Operation flowchart of retrieving and viewing images.**
Based on the above requirements, in 1989 we began designing a system for integrating medical images into a total HIS as follows. The total HIS, the IDS and the terminal PCs were linked to each other via a local area network (LAN). Next, the image retrieval function was added to the main menu of the operation screen of the total HIS. The operation flowchart for retrieving and viewing images on the terminal PC was designed as shown in Fig.1. Based on the above concept, a picture archiving and communication system (PACS) integrated into the total HIS was later called a second generation PACS [11].

Since two operation screens, that of the image viewer and the total HIS, should be dynamically controlled, the terminal PC operating system was required to support multi-tasking and multi-windows. The resolution of the CRT was assumed to be 8-bit gray scale and 1280 x 1024 pixels. The image acquisition from diagnostic equipment such as CT and magnetic resonance (MR) scanners was designed as follows. Images produced by diagnostic equipment were automatically transferred to a gateway at the radiology center. The original image data file was converted to ACR-NEMA ver.2.0 format [12], then compressed at the gateway, and was transferred to the IDS via LAN. Due to the following, the ability of the terminal PC, the capacity of the IDS and the speed of image transport, the rate of compression was approximately 1/10. In addition, the gray scale of CT and MR images was reduced from 16 bit to 8 bit.

3. The test run

3.1 Test run system configuration

In October 1995 we started the test run. The system configuration and circumstances for the test run are shown in Fig.2 and Table 1, respectively. Since the hospital’s terminal PCs were not capable of running the image viewer software, eight new Intel DX4 100 MHz PCs were installed hereafter called the image viewing terminal PCs (IVT-PCs). The IVT-PCs were installed in the seven ward conference rooms and in the radiology department conference room. After considering the cost, performance, reliability and ability of the UNIX server, the IDS was developed on an IBM mainframe. As a result, the System Networking Architecture (SNA) protocol was used as the communication protocol between the IDS and the IVT-PCs since the SNA protocol is the only protocol supported by the IBM mainframe.

| Table 1. The circumstances in the test run. 
The symbol $\rightarrow$ means the change in the period of the test run. |
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Host of IDS</td>
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<tr>
<td>Capacity of IDS</td>
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<tr>
<td>Resolution of CRT</td>
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<tr>
<td>No of IV-TPCs</td>
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<tr>
<td>CPU of IV-TPC</td>
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<tr>
<td>Operation system of IVS</td>
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<td>Modalities</td>
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<tr>
<td>Communication Protocol</td>
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Fig.2 The system configuration in the test run

CT and MR exam images for all inpatients were stored in the IDS. After the completion of each CT exam, the scanned images were immediately and automatically transferred to the IDS through the radiology department gateway. The control system of the MR scanner did not allow immediate and automatic transfer of images, therefore MR scanner images were batch transferred to the IDS at the end of each day. Due to the capacity of the IDS only two months worth of CT and MR exams could be stored on the system. There-
fore, stored images more than one month old were deleted from the IDS at the end of each month.

3.2 Test run evaluation

Since the IDS existed on the same mainframe running the total HIS, the access time to retrieve a list of exams for one patient from the IDS was a few seconds. However, using an IVT-PC the time to acquire fifty CT images from the IDS was approximately three minutes. As images accumulated on the hard disk of the IVT-PC the image acquisition time increased. In the test run doctors could access images after the radiologist’s reports were registered on the IMIS because the image quality on the CRT was not high enough for reliable diagnosis. Therefore the doctors could access images on the IVT-PC, when the corresponding hard copy had arrived at the doctor’s lounge of the ward. In comparison with the time taken finding a specific film in the film holder bag, the time taken to acquire images from the IDS using the IVT-PC (three minutes) was too long. As a result, the utilization of the installed IVT-PCs was very low.

The location and small number of IVT-PCs may have contributed to this low utilization. In January 1997 the number of IVT-PCs was increased from 8 to 60 and two or three IVT-PCs were installed in each doctor’s lounge in each ward. However, only a slight improvement in the utilization of the IVT-PCs was seen. The number of times images were acquired from the IDS using the IVT-PCs was on average approximately 30 times per week. Thus we inquired as to the doctor’s requirements of the IVT-PC. The results of the inquiry raised the following points: doctors required the image accessing time to be at least less than a half minute and if possible less than 10 seconds; the images should be immediately available on the IVT-PC after an examination because the CRT images were useful for tentative diagnosis; the period for keeping images on the IDS should be more than a half year, because comparisons between the present exam and the previous exams were necessary.

4. Improvements and evaluation

4.1 Improvements

The causes of the slow image access time found during the test run were investigated and two main causes were found. One cause was due to the slow communication speed between the IDS and the IVT-PC. Although a much higher communication speed could be realized using a 16 Mb/s token ring LAN, the communication speed realized by the LAN used during the test run was only 400k bits/s (b/s). This slow communication speed was due to the SNA protocol and the existence of a communication controller between the mainframe and the IVT-PCs. Another cause came from the processing time required to create preview images on the IVT-PC by using images transferred from the IDS. Preview images were 128 × 128 pixels and were used to display twenty images on the CRT at once. If preview images were not created beforehand at receiving images from the IDS, it took a long time to display the preview images on the CRT although the image access time could be reduced.

During the time taken for the test run the cost, performance, reliability and ability of the UNIX server improved a great deal, thus we adopted the UNIX server as a host computer for the IDS. As a result, this resolved the reduction in communication speed caused by the SNA protocol and the existence of a communication controller. Because the UNIX server can be directly connected to a LAN without a communication controller and supports the Transmission Control Protocol/Internet Protocol (TCP/IP) protocol, which is much simpler than the SNA protocol. Also during the time taken for the test run much more powerful PCs became available. These more powerful PCs took only a few seconds to create preview images from received images and to display those on the CRT. Therefore it was not necessary to create preview images beforehand.

The configuration and circumstances of the renewed system are shown in Fig.3 and Table2, respectively.

Table 2. The circumstances of a renewed system

<table>
<thead>
<tr>
<th>Host computer of IDS</th>
<th>3×UNIX server</th>
</tr>
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<tbody>
<tr>
<td>Capacity of IDS</td>
<td>400GB</td>
</tr>
<tr>
<td>Resolution of CRT</td>
<td>1024×768 with 16bit colors</td>
</tr>
<tr>
<td>No of IV-TPCs</td>
<td>239</td>
</tr>
<tr>
<td>CPU of IVT-PC</td>
<td>Intel Pentium 166MHz</td>
</tr>
<tr>
<td>Operation system</td>
<td>Operation System 2</td>
</tr>
<tr>
<td>of IVT</td>
<td></td>
</tr>
<tr>
<td>Modalities</td>
<td>2×CT, 2×MR, 2×CR, 3×ES</td>
</tr>
<tr>
<td>LAN</td>
<td>155Mb/s ATM-LAN (backbone)</td>
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<td></td>
<td>25Mb/s ATM-LAN</td>
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<tr>
<td></td>
<td>16Mb/s token-ring LAN</td>
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<tr>
<td>Communication protocol</td>
<td>TCP/IP</td>
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The IDS consists of three UNIX servers with a total capacity for storing images of approximately 320 gigabytes. We were able to install the IDS equipped with such a large capacity because the cost of the hard disk for the UNIX server in 1995 was 1/18 of that for the mainframe installed in 1989. In addition, when the IMIS was renewed in January 1997 a large capacity asynchronous transfer mode (ATM) LAN was installed because all clinical terminal PCs were planned to be replaced by the IVT-PCs and also one MR scanner, two CR and three endoscopes (ES) would be connected to the IDS. These changes resulted in a communication speed of approximately 16 Mb/s.

4.2 Evaluations

The total processing time required to acquire 50 CT exam images from the IDS using an IVT-PC was reduced from three minutes to 16 seconds as a result of the various improvements explained in section 4.1. Because speedy access was one of the most attractive merits of the system and because we recognized that the quality of images on the CRT was high enough to allow tentative diagnosis, doctors are permitted to view images without the accompanying radiologist’s report. As a result, doctors are able to view images of radiology exams (CT, MR and CR exams) within a few minutes after the completion of the exam. Figure 4 shows data flow for the data storage and referral stages of lab exams and imaging exams. In both cases, after completion of an exam the results are automatically stored in a short time in database systems which can be accessed by doctors using the operation screen of the total HIS. The only referral differences between these two types of data are that the imaging exams require an additional image viewing window and longer processing time (from several seconds to twenty seconds) to acquire the data for display. Indeed until now we have received no serious complaint from doctors regarding the exam image retrieval, acquisition and viewing operations.
The improved system was started in August 1997. Since the end of September 1997, outpatients CT and MR exam images were made available in addition to those of inpatients. In November the processing time to acquire images was reduced a further 30% by improving the method of image transfer. The viewing of CR images and endoscopic graphs in the improved system were introduced at the beginning of April and the middle of May 1998, respectively. The number of times a week images were acquired from the IDS using the IVT-PCs is presented in Fig.5 for the term August 25 1997 to May 17 1998. During the test run of the original system, the number of times a week images were acquired from the IDS using the IVT-PCs was 30 times on average. However, after the improved system was introduced a seven fold increase was seen compared to the original system. From the analysis of image accessing log we found that the access ratio of new CT and MR exam images were 40 percent and 30 percent, respectively.

Complaints were received from doctors regarding the quality of CRT images and the method for comparing two exams. Both problems stem from the hardware limitations of the installed CRTs and PCs. As shown in Fig.6, in the present system a comparison between two exams is realized by dividing one display into two windows. However, doctors who are unfamiliar with PC operation have difficulty performing this comparison. Of course, this problem can be resolved by using two CRTs which will require double the space and additional cost. If all IVT-PCs were equipped with two standard CRTs, the total additional hardware cost becomes approximately US$360,000, assuming that an additional standard 17 inch CRT and a multi-display adapter estimated to be US$600 and US$900, respectively, are used for each IVT-PC. However, if two 15 inch liquid crystal displays (LCDs) are used to save space, the cost becomes US$700,000, for a 15 inch LCD estimated at US$1,000.

In the improved system the display mode is set to 16 bit color mode using the available video random accessing memory (VRAM) of the IVT-PC, and the renewed image viewer software uses the color map of the operating system. As a result, the actual gray scale range of the CRT is from 0 to 31 although the gray scale of the image data is 8 bit. Therefore, occasionally the CRT images of MR exams are unclear. By the end of March 1999 we intend to increase each IVT-PC’s VRAM which will allow us to set the display mode to 24-bit color mode. These improvements will enable doctors to view higher quality images on the CRT.

After the CR image service was introduced we recognized that the quality assurance of digital images was also a very important subject, as pointed out by Tucker et al. [10]. Since the number of CT or MR
exams produced from each piece of image acquisition hardware is less than ten per day, very rarely is the wrong patient’s information attached to an image. However, in comparison the number of CR exams per day is considerably more and the time spent on each exam is short. Therefore, errors are more likely to occur. We found that the error derived from miss-operation occurred a few times per week. Since digital images after the completion of each CR exam are immediately transferred to the IDS, there is the possibility that such errors may lead to doctor’s misdiagnosis.

5. Discussion

We successfully integrated medical images into the total hospital information system (HIS). During system development we found that several conditions should be satisfied in order to make the integration effective and attractive to doctors. Those conditions are summarized as follows:

- The image viewing station and the total HIS operating terminal should be combined.
- Operations for image viewing and those for the total HIS should be unified.
- The processing time to acquire the images of one exam from the image database system (IDS) to the image viewing station should be less than a half minute.
- After the completion of each exam, the digital images should be made available to doctors before arrival of film images.
- The method for comparing two exams on the CRT should be as easy to use as comparing two hard copies.
- The quality of images on the CRT should be high enough for diagnosis.
- The quality assurance system for digital images should be established.

The present system satisfies the first four conditions and special attention was paid to the image access speed. As a result, doctors can view images within approximately a few minutes after the completion of the exams, using this system. Arenson et al. pointed out that fast image access at an intensive care unit (ICU) was very effective for the rapid care of a patient [13]. We believe that fast image access after the completion of an exam is also very attractive for outpatient care because outpatients can waste up to two hours waiting to hear an exam result from their doctor. Furthermore, occasionally outpatients cannot hear their result the same day and have to make another appointment.

The present system did not sufficiently satisfy the last three conditions listed above. If an LCD is acceptable for displaying medical images, then we expect that the problems encountered comparing multiple exams using the present system will be solved in the near future at the current rate of progress of computer technology. The image quality of the CRT is a rather troublesome subject. Although the gray scale of the CRT's used is 5 bit, 50% of doctors said that the digital images of CT and MR exams could be used for diagnosis. If the gray scale of the CRTs used was improved to 8 bit, we believe that for diagnosis the number of doctors satisfied with the digital image quality will significantly increase. Parasy et al. [14] reported that there were no statistical difference for diagnosis between a PACS diagnostic workstation and PC-based workstation with a resolution of 1024 × 768 pixels and 8-bit gray scale. However, the gray scale of original CT and MR images is 16 bit and we believe that for diagnosis 12-bit gray scale is acceptable. Therefore, even if the gray scale is improved to 8 bit a lot of information will be lost. We emphasize that images viewed on the CRT should be used for reference. If doctors make a tentative diagnosis using images on the CRT doctors should reconfirm diagnosis using either the radiologist’s report or the hard copy. These limitations decrease the value of the present integrated system. Therefore we urgently require a PC which in color mode is able to handle 12-bit gray scale and to display images in the 9- or 10-bit gray scale.

Quality assurance is not only a subject effecting the digital imaging system, but also a subject of consideration for the total HIS. In order to establish quality assurance, a lot of effort has been spent improving the online system of the lab exams. Error types have already been investigated by Tucker et al. [10]. Based on such a study, we have to promptly establish the quality assurance system in the online system of the imaging exams.

Finally, we comment on the influence of LAN capacity on the integration of images into the total HIS, because the capacity problem of LAN in the PACS has been a subject of discussion in the past [15,16]. As mentioned in section 3.1, we installed an ATM-LAN assuming a future increase in the number of image acquisition equipment and image viewing terminal PCs (IVT-PCs). As a result, we found that the current number of images is accessed does not warrant the ATM-LAN. The total processing time to acquire images from the IDS using an IVT-PC via a 16 Mb/s token ring LAN is almost the same as that via a 25 Mb/s ATM-LAN. This is because the processing speed of the IDS and IVT-PCs is much slower than the communica-
tion speed of the ATM-LAN.

References