

Integration of Database Capabilities into a Patient Reporting System

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A database design is described which automatically archives computer-generated patient imaging and radioassay reports. Selected phrases are condensed so that data storage will be efficient without sacrificing a prose style of report. An indexed file structure has been used to facilitate rapid record retrieval even when several hundred thousand records are stored. Personnel time is considerably reduced for recalling patient records, preparing periodic summaries of studies completed, and performing administrative functions such as billing and keeping track of checked out images. Complex queries, such as "list all the patients between the ages of 50 and 60 on digitalis referred for a stress cardiac study, with left ventricular ejection fraction less than 40% and apical dyskinesis," become feasible. A system for data backup is described to protect against catastrophic data loss.

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Decreasing expense and increasing performance of multi-user computer systems indicate that application of computers to generate and store patient information for rapid retrieval will eventually become widespread even in relatively small nuclear medicine departments. Much time and money have been invested in computerizing imaging departments both in scheduling-reporting activities and archiving images (1-5), with most such activities being concentrated in diagnostic radiology departments. A logical extension of report generation would include saving the demographic data and clinically important findings of each study in a permanent database. Archiving this data has the advantages of allowing rapid recall for review, easing preparation of statistical summaries, and facilitating clinical research studies on large populations. We have linked the process of automated patient report generation on a minicomputer, for both imaging and radioassay reports, to the permanent storage of this data in such a way that archiving is automatic and completely invisible to the user.

MATERIALS AND METHODS

Ideally, report generation and data archiving would be

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available on a centralized hospital computer system to enable reports to be accessed on a terminal at any nursing station. However, busy hospital data processing departments usually have low interest in creating applications specific to individual departments on their already heavily burdened computer. Nuclear medicine departments frequently have their own image processing minicomputer, but vendors have provided minimal software applications for report generation and archiving, usually in a relatively awkward form that uses a tedious question and answer approach to capturing information. This is due, in part, to the lack of some necessary hardware. At this time, microcomputer networks suffer when compared with a minicomputer from a lack of operating system sophistication, speed, and complexity of static screens (the ability to fill an entire terminal screen with prompts, allow the user to fill in different areas in random order and read the entire screen back), which can be created by the user. In addition, the microcomputer network system would probably not cost much less (considering the expense of a file server and disk for the network and a similar number of terminals and printers) and would likely be composed of several different manufacturer's components, making service arrangements more complex.

Specific hardware requirements for a functional report generation system are described in a previous publication (6) and include static screen capability for terminals, fast terminals (read the current screen and display a new screen in a fraction of a second), and printer spooling (the ability to send the printing assignment to the disk and then to a printer when available, so that the user can proceed immediately to the next task without waiting for the actual printing to take place).

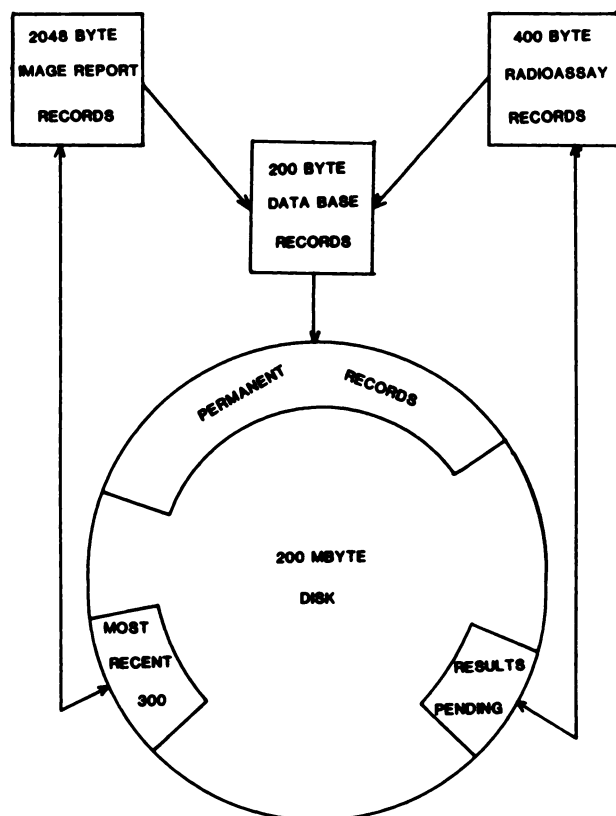


FIGURE 1
Organization of disk storage for prose-style imaging reports, pending RIA reports, and resulting permanent database records

These requirements can be met by most small general purpose business computers but may not be present on image processing computers with which most nuclear medicine personnel are familiar with. We are now using a minicomputer* with a 200 megabyte disk and 512k bytes of memory. A magnetic tape drive to copy the database file at the end of each day was selected as the most practical means of insuring against data loss. Data base packages which assist the development of an information storage and retrieval system can either be acquired from a software vendor and integrated into a report generation system, or developed by the user.

After 3 yr of using computer-generated reports exclusively, we have found that patient imaging reports are well accepted by the referring physicians when read as conversational prose. However, searching for a particular combination of study findings in a large amount of data is not practical in a report which is entered in an unstructured, freehand style. Furthermore, the space consumed by freehand text makes archiving impractical. Our approach in designing the report generation software relies on pre-established prose phrases that will appear in the printed report, but uses only a short code to represent each chosen item in the condensed database record (Fig. 1). A 200 byte record (1 byte corresponds to one character) was selected as adequate to store the important information for each patient, using 110 bytes for demographic and bookkeeping data, 70 for selected clinical findings, and 20 for numerical data such as ejection fractions and thyroid uptakes. Since there are several hundred selectable clinical findings in some report types, only those 70 in the report judged to represent information of high research interest are coded for archiving.

A brief example using one of the stress thallium screens illustrates how sentences and numbers are coded and stored

CMD3=advance page
ENTER=branch back

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AUTOMATIC NORMAL: 01
- MYOCARDIAL THALLIUM DISTRIBUTION IS PHYSIOLOGIC. 02

X THERE IS DECREASED TRACER CONCENTRATION IN THE # MYOCARDIUM. 03
  - SEPTAL, 04
  - POSTEROLATERAL, 06
  X INFEROPOSTERIOR, 08
  - APICAL, 10
  - LEFT VENTRICULAR, 12
  - INFEROAPICAL, 05
  - ANTEROSEPTAL, 07
  - INFERIOR, 09
  - ANTEROLATERAL, 11
  - RIGHT VENTRICULAR, 13

- TRACER DISTRIBUTION IS OTHERWISE PHYSIOLOGIC. 14
- THERE IS AN IRREGULAR TRACER DISTRIBUTION IN THE MYOCARDIUM. 15
X THE LV CAVITY IS DILATED. 16
- THE LV WALL IS THICKENED. 17
- THE INTRAVENTRICULAR SEPTUM IS THICKENED. 18
- THE RV CAVITY IS DILATED. 19
- THE RV WALL IS THICKENED. 20
- TRACER CONCENTRATION IS INCREASED IN THE RV. 21
X TRACER ACTIVITY IS INCREASED IN THE LUNGS. 22
- THE MYOCARDIUM/LUNG ACTIVITY RATIO IS _____. 23
  
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PAGA1A1

FIGURE 2
One of several stress thallium screens. Selected phrases will appear on printed report and code positions 3,8,16,22 in clinical findings table will be flagged in database record

CMD4=exit,no update		CMD5=save report		CMD16=delete report		CMD8=file into DBASE	

NAME: SMITH, JANE		BIRTH DATE: 082853		SEX: F		HOSP# 1234567 NM# 654321	
DATE RECEIVED: 102384		IN/OUT PATIENT: I		ADMISSION DATE: 102084		DRG: ---	
HOSP(S/T) S REASON FOR STUDY: ---		REQUESTING PHYSICIAN: SIMMONS, ROBERT		---		---	
COST CENTER: 502		COLLECT DATE: 102384		COLLECT TIME: 0800		---	

PROCEDURE	RESULTS, UNITS	NORMAL-RANGE	REPORT-DATE	REPORT-TIME	SENDOUT?		
4011	34.--- %	35.---45.---	102484	PM	N		
4012	8.2--- MCGDL	5.5---11.5	102484	PM	N		
4013	-----	-----	-----	---	-		
4029	-----	-----	-----	---	-		
----	-----	-----	-----	---	-		
----	-----	-----	-----	---	-		
----	-----	-----	-----	---	-		
----	-----	-----	-----	---	-		
----	-----	-----	-----	---	-		
----	-----	-----	-----	---	-		

RIAP400

FIGURE 3
Four RIA studies are recorded on this record in the pending file. Procedure is identified by four digit billing code (4011 = T3, 4012 = T4 RIA, etc.). When designated key is pressed, two completed studies will be archived into database, and other two will remain in RIA pending file

(Fig. 2). For each descriptive phrase selected to appear in the written report, any two digit code following the selection causes a specific byte in the 200 character database record to be marked. Certain numerical values, such as regional tracer washout, will be saved in the numerical data section of the database record. After several similar screens of selections, the report is marked "verified" (equivalent to signing) by the physician and printed. At this point, two separate archiving events also occur; the entire 2,048 byte report is saved in a temporary file that holds the prose text for the most recent 300 reports, and a corresponding 200 byte record is added to the permanent database file. Since information is added to the database file only when the final document is printed, the verification made by the physician before printing helps assure the accuracy of this file. The problem of more than one person attempting to modify a given report at the same time from different terminals is resolved by allowing the first person to make changes in it while others can only view it until the original user releases the record.

Our radioassay laboratory results are also inserted into this database. For these studies, a 400 byte "pending" report containing up to eight tests per patient (Fig. 3) is created. This is needed since some samples are sent to reference laboratories and results are not available for several days. As results become available, this report is broken down into one record for each test and stored in the database file. Although the type of information stored is different from the imaging reports, the demographic portion and keyed fields are identical, allowing imaging and radioassay records to be mixed together and accessed in the same manner.

Once a database record is stored, the record must be retrieved for any subsequent interaction. The organization and

structure of a database file and the sophistication of the software has a great impact on the speed of retrieval of individual records. If the software is designed to locate a patient record by reading each record from the beginning of the file and comparing a piece of data in that record to the requested parameter, such as patient name, for a match, retrieval time will become unacceptable after a few thousand records. Indexed files (such as those used in airline reservation systems) are the most popular means of speeding up searches (7). This approach is completely analogous to a library card catalog with subject, author, and title indices for each book. Whenever a new book is added to the library, an index card is created for each of these parameters and filed in sequence in the respective card catalog. When looking for a book, instead of starting with the first book in the front of the library and looking at each one to find the desired volume, one goes to the card catalog, chooses an index or "key" to use for the search (i.e., subject, author, or title), determines the physical location of the book, and retrieves the book directly. For our purpose, several parameters in the patient record are designated as keys and a separate file containing an indexed list is created for each key. We have selected patient name (using the first 12 of the 20 name characters), patient's hospital number (seven characters, available in case the patient name is misspelled), study-type (the four digit billing code is used), and date of study (6 characters, could be used together with study-type key to quickly display a list of all bone scans performed on 10/23/82, for example) as sufficient keys to satisfy most needs for rapid retrieval. When a new record is added in chronological order to the database file, the patient name, number, study, and date are each added to their respective indexed lists in alphanumeric order. To retrieve a

record, one or more of the keys are specified and the computer searches rapidly through the corresponding indexed list, finds the matching key, and reads the corresponding physical location of the desired record on the disk. The increase in speed therefore comes from two sources.

1. Unlike the actual records, the keys are sorted into alphanumeric order allowing the computer to jump quickly to the approximate location of the key in the list without the need to read all of the preceding keys.

2. The computer searches only the list of short keys rather than reading the entire corresponding 200 byte record, so many more can be read off the disk for examination at one time.

To make selection of a study simpler, once a record matching the specified key is located, that record plus the next 19 alphanumerically sequential records are displayed in abbreviated form. From this list the desired record is selected, which is then displayed in expanded form, allowing the user to pick a study out of several performed on this patient, or the correct John Smith, for example. If the desired study is not displayed, pressing a designated key will display the next 20 studies in alphanumeric order. Although all these features may seem to be a complex programming task, some languages such as COBOL have this indexed file structure built-in as an option.

Our laboratory performs about 40,000 imaging and radioassay tests each year. Our goal is to keep the most recent 5 yr in the database file. An important consideration is choosing an alternate medium to copy and store daily the database from the disk to avoid accidental loss. The number of records one can conveniently store in a single file is often dictated by the capacity of the back-up medium rather than the much larger disk. With recent innovations in "streaming" data onto magnetic tape (writing nonstop in a restricted mode at high speed with all the inter-record gaps and other industry standard markers removed), ~200,000 patient records can be copied to a 2,400 foot tape operating at 1,600 bits per in. in 4 min. These tapes are stored at a remote location (i.e., far enough away so that any catastrophe such as a fire or vandalism would not affect both the data on the computer and the tapes). Five tapes labeled "Monday," "Tuesday," . . . "Friday" are rotated and used as backups only on those days. This minimizes the possibility of unwittingly copying injured data from the disk onto the most recent backup tape leaving both ruined. The act of recovering from a data loss would then be to read the magnetic tape copy from the previous day back onto the disk, and then apply the changes that had accumulated during the current day.

DISCUSSION

In our system, retrieval and display of a specified record by one of these keys requires ~1 sec to retrieve one record in a 200,000 record file if there are no concurrent intensive disk read or write activities from other users. At peak activity levels, there are typically three secretaries word processing, one secretary generating administrative statistics from the database, five physicians and technologists processing patient reports, and one programmer involved in software development. About 95% of this activity involves interacting with a

static screen on a terminal, which places no demands upon the CPU or disk itself. Only 5% requires use of the disk and occasionally stretches the retrieval time for a record to 3 or 4 sec if more than one request is competing for the same disk drive. Dividing disk storage into two separate units with one reserved for database files would alleviate this problem. For a complex research query, the study-type key is used to quickly retrieve each study of a specified type, for example liver scan, but then the contents of each liver-spleen record must be examined to see if it satisfies the request. This is analogous to reading each library book on a specific subject to see if it contains the desired information. Since this requires considerably more computer time, searches like this would be best confined to offpeak hours if there are many thousands of liver scans to be examined in the database file.

In addition to rapid recall of individual records for review, many administrative tasks can be easily accomplished once the database is established. The entire file can be scanned to produce daily billing lists that can be transported to the hospital's billing computer system on magnetic tape. Spreadsheets can be generated between any given dates showing the number of each study-type performed, separated into different categories (such as inpatient compared with outpatient status), with study totals and revenue totals on each line and column, making weekly, monthly, or annual summaries simple. Archiving the injected radioactivity would allow tables of average activity to be generated for each study. Tables showing the number of patients referred from each primary care service and the reason for referral can be compiled. Numerical information such as normal values for a radioassay test, average thallium washout for different segments of the myocardium, and typical increases in left ventricular ejection fraction between rest and stress in normal and abnormal patients can be computed. Other improvements include avoidance of misfiled records and availability of a single record to different parts of the laboratory at the same time. Information can be added directly to the database record, retrospectively, to ease keeping track of teaching cases through American College of Radiology (ACR) diagnostic codes input at the completion of the report and to keep track of DRG assignments on each patient.

CONCLUSIONS

We have presented a computer database system developed to extend computer generated patient reports for the archival of important data on a departmental minicomputer system. This has been achieved using a design that requires no extra personnel or effort. We have found no practical system available from commer-

cial system vendors. Our experiences can serve as a guide for developing a practical system on a multi-user minicomputer where these capabilities can be delivered to many areas of the department including the locations of central patient processing, physician dictation, radioassay, radiopharmacy, and technologist stations.

Converting from a manual means of storing and retrieving information on patient studies to the use of a computer should be carefully planned with sufficient overlap to allow thorough elimination of program flaws. A common initial concern is the fear of losing data or not having access to it if the computer hardware fails. Careful planning can facilitate speedy recovery from accidental data loss. Hardware for the newest generation of business computers is very reliable, insuring virtually continuous access to the patient data. The two computers we have used over the past 4 yr since we implemented this system have had a combined total of only two hardware failures, and were repaired in less than 5 hr in each case.

FOOTNOTE

* IBM System/360.

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