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THE UNMH INTENSIVE CARE INFORMATION SYSTEM

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We describe the computerized information system recently set up in the Newborn Intensive Care Unit at Bernalillo County Medical Center (BCMC) which has since been renamed the University of New Mexico Hospital (UNMH) in Albuquerque, New Mexico. The physical layout of the system is described, as well as the controlling program. It is a "menu" driven file system. This facilitates data protection, as well as providing modular access and easily alterable use of the data. Several features of the system, such as automatic report generation and query by example, are explained.

Introduction

Recently, several computerized intensive care information systems have been described in the computers and medicine literature.[1,2,3] Some of these, besides our own, have been placed in newborn intensive care nurseries.[1] The goal of the computer data management system is to improve the medical care within the intensive care unit by making the data collection more manageable on a daily basis and thus freeing the medical staff for more urgent needs. The information system can directly contribute to medical care by making important information immediately available to the medical staff. The system can also assist in "medical reasoning," i.e., intelligent manipulation of the data to improve medical care.[4,5,9] While a full implementation of this last goal is still some way off, we have taken the necessary steps with the "menu" driven file system, automatic report generation, and query by example routines described below to institute such a system.

Hardware Description and the Terminal/Printer Layout

It has been an important goal of this project to construct an intensive care system run mainly by the medical personnel with very little assistance from the computer science group. There is also continuous developmental effort by the system designers to improve the system, by adding new menus or further report possibilities to the system. However, we found it important that the medical staff alone be responsible for all entry and manipulation of the data.

The programs are written in UNIX 'C' language[6,7] on the Digital Equipment Corporation PDP 11 computer. The choice of 'C' was made both for its higher level language capabilities and its general availability. The information system has already been hosted by two computers, a PDP 11/34 and a PDP 11/70. It is still on these rather large minicomputers for developmental reasons, i.e., for the time-sharing and operating system capabilities. Ultimately, we see the system running on a much smaller stand alone machine, perhaps an LSI 11.

Figure 1 illustrates the computer-terminal-printer layout. The terminal, a Haseltine 1500 (CRT) is connected directly by a 1200 baud line to the PDP 11/70. We found the 1200 baud rate to be necessary since a great deal of data was transferred back and forth to drive the menu program (see below). The hard copy printer is connected locally to the CRT. This allows the new or updated files of the patients to be printed on hard copy when desired and to be physically entered into the patient's record book. The records are, of course, still contained on disk, as well as periodically backed up on tape.

There are computer generated tables for the patient diagnoses, procedures, and coded menu answers known to the computer near the CRT. This allows the CRT operator to have, conveniently at hand, the codes used for much of the data given to the computer.

Besides the codes, there are blank fields in the record where new diagnoses or physician comments may be added to properly describe the medical situation. The coded-answer entry to the data system has many advantages, the most important being the CRT operator need not spell out or repeatedly type complex diagnoses and procedures. Thus, there is no need for special spelling correction or long sentence handling routines.

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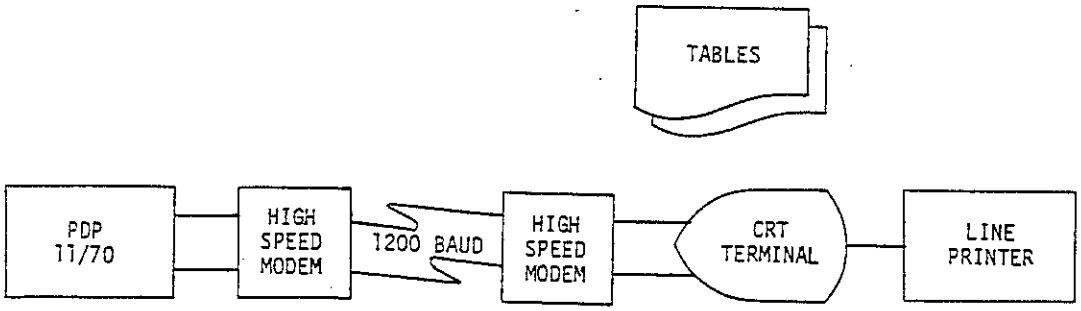

Figure 1. The PDP 11/70 computer connected by 1200 baud lines to the CRT. The hard copy printer is connected locally to the CRT. The tables of diagnoses, procedures, and coded menu answers assist the operator in entering proper codes. The total cost of terminal, printer, and high speed modems is about $3000.

The preparation of the admit information and the diagnosis and procedure details made up a good bit of the work of the medical staff in constructing the system. It was necessary to carefully and exhaustively identify the information they wished to make available for most reasonable situations. Once this work was done, however, it was very easy to enter information into the file system. If, for example, the diagnosis of an infant was a respiratory infection, such as suspected pneumonia, and the disease was manifest after 72 hours of age, the CRT entry under the diagnosis menu would be "A.4.1.2." The table available to the CRT operator would indicate this from approximately 400 diagnoses. The format of the diagnoses on the table printout is:

```
A.  RESPIRATORY
      1. TRANSIENT-TACHYNEA
      2.
          ....
      3.
      4. PNEUMONIA
          1. EARLY ONSET (<72HRS)
               1. SUSPECT
               2. PROVEN
          2. LATE ONSET (>72HRS)
               1. SUSPECT
               2. PROVEN
      5. AIR BLOCK
           ....
```

Once the symbols, "A.4.1.2," and the symbols for any other relevant diagnoses are keyed-in, the operator depresses the "return" key. On the reply menu from the computer, "RESPIRATORY-PNEUMONIA-EARLY-ONSET(>72HRS)-SUSPECT" replaces the symbols "A.4.2.1" on the screen. Thus, the words rather than the symbols are printed on the patient's permanent records and are always available to double-check the keyed-in symbols. Data entry by symbols is meant to greatly simplify the effort of entering data into the system. The rather rigid format for diagnosis and procedure information is necessary for future uses of the data, for example, in query by example and report generation. If we ever will be able to automatically answer the question, "In the past six months, how many of our babies of less than 1000g birthweight had suspected pneumonia?", we will need the rigidly controlled information structure below the menu level and unseen by the CRT operator. This will be further described in the next section.

System Design

Figure 2 shows a top level view of the system. It is menu driven in that the only way data may enter and leave the data files is through the system of menus. This is an important approach to data storage and retrieval for several reasons.[8] The most important is that the operator cannot alter or rearrange the file systems, he or she may only enter or change the data contained in the files. The files are "hidden" from the operator. All that is seen is one of the set of menus on the screen asking for different bits of information. There are some fields in the menu that must be filled in, such as the INFANT'S CHART # on the admit menu, or an error symbol will appear to remind the operator that the admit menu is incomplete.

The menus are designed using the "foreground/background" modes on the CRT. With this approach, the questions are printed at one brightness level on the screen and the entered responses to these questions appear at another brightness level. The set of "tabs" for each menu is arranged so that by touching the "tab" key, the cursor automatically skips to the appropriate location for the next response. Each menu has been designed to fit on the screen all at one time, so that the operator will not need to scroll up or down to view all the response locations.

The menu approach to data entry also provides a good deal of modularity for the entire system. For example, one nurse can be assigned to do admit and history information for each new child admitted. A physician may enter the daily diagnosis and procedure information, and a third person may handle discharge information and generate reports. The menus may be further used to protect the data base by allowing certain people to use particular menus.

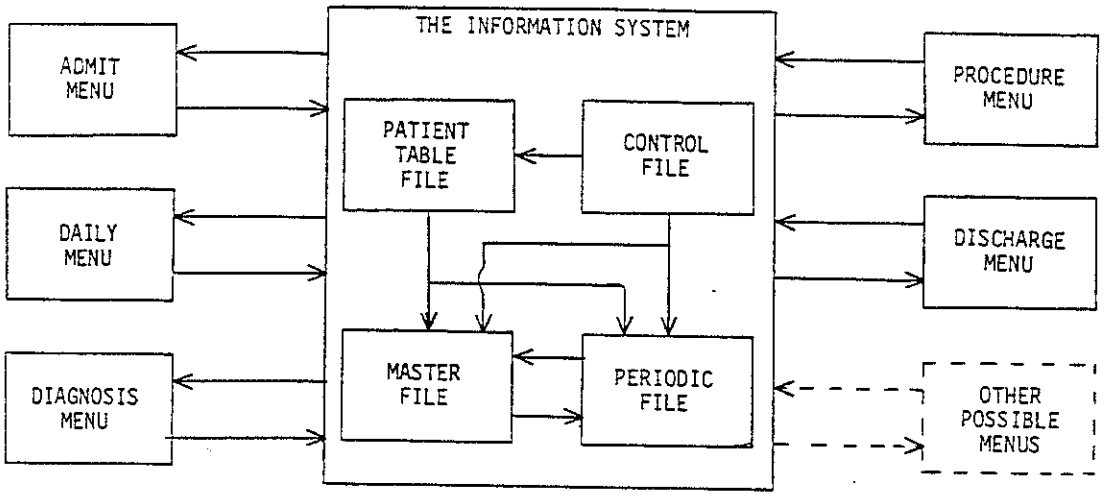

Figure 2. A "top level" view of the system. It is a "menu driven" system in which the fields of the data records are hidden and therefore protected from inappropriate operator access or use.

This approach can also meet the privacy requirements for sensitive medical records. A sample menu is illustrated in Table 1.

When new sets of data are required for the information system, new menus may be created with appropriate links to the files. For example, UNMH provides newborn intensive care service for quite a large section of New Mexico and some of the surrounding states, so we are considering collecting information on the transport methods for bringing the infants to the hospital. All that is necessary to make this expansion is to design a new menu for the transport team that provides the appropriate information for the records. In this case, the menu may be restricted for use by the transport team and they may be barred from using other menus. It is also possible to alter the existing menus if new or different information is desired. This, of course, must be done by the system design personnel and, as was true with the menu protection, others may not have access to these files. This provides good flexibility within the system and prohibits accidental or deliberate damage to the medical records.

TABLE 1. THE ADMIT MENU. THE CAPITOL LETTERS INDICATE THE MENU SPECIFICATIONS THE LOWER CASE LETTERS AND DIGITS INDICATE SAMPLE DATA ENTERED.

1	INFANT'S CHART #	654321		
2	LAST NAME	patient		
3	HOME ADDRESS	2123 1st, hometown		ZIP 00000
4	MOTHER'S CHART #	123456	AGE	23
5	SEX	m	RACE	HISPANIC
6	DATE OF ADMIT	81280	TIME OF ADMIT	1002
7	TYPE OF ADMIT	MATRNL XFER	UNIT OF ADMIT	NBICU1
8	MODE OF TRANSFER	AIR	TRANSFER BY WHOM	XFER TEAM
9	REFERRING MD	doc		
10	REFERRAL HOSPITAL	hmc		
11	HOSPITAL OF BIRTH	hmc		
12	DATE OF BIRTH	81180	TIME OF BIRTH	2256
13	MULTIPLE BIRTH	y	BIRTH ORDER	2
14	TEMP ON ARRIVAL	35	TEMP ON PICK-UP	36
15	BIRTH WEIGHT	2345	ADMIT WEIGHT	2344
16	LENGTH	34	OFC	23
17	GESTATIONAL AGE	34	WEIGHT WRT GEST AGE	a
18	MOTHER'S GRAVIDITY	2	MOTHER'S PARITY	3
19*	DELIVERY TYPE	VAGINAL	DELIVERY POSITION	3
20	MOTHER'S BLOOD TYPE	o+	INFANT'S BLOOD TYPE	o+
21	COOMBS	n	1 MINUTE APGAR	5
22	5 MINUTE APGAR	6	10 MINUTE APGAR	7
23	MOTHER'S SEROLOGY	n	INFANT'S SEROLOGY	n
24	COMMENTS	none		

The diagnoses and procedure menus are filled-in each day by the attending physician. It is most important that the diagnosis and procedure menus be seen as the primary method of recording the data. If a hard copy record of diagnoses and procedures is required by the medical personnel, the line printer copy of the menus should be used. It would be subversion of the entire enterprise for the attending physician to write out their diagnoses and procedures and then expect other staff members to "put it in the computer."

The daily menu contains a summary of the prior diagnoses made and procedures taken for the child. This cumulative data is presented to assist the doctor in seeing, in a comprehensive fashion, the hospital history of the child. This daily updated summary can be printed out to replace the previous day's summary in the patient's records eliminating duplication in the infant's record book. For example, the day the patient started receiving breathing assistance and when this was discontinued, or when the patient received special procedures and how many times they were performed.

The discharge menu containing administrative and final diagnosis and procedure summaries complete the permanent records of the patient retained on the computer. After the patient is discharged, these will be retained for future report generation and to collect any other information desired. The total information of all data collected during the hospital stay will also be saved on tape for future inquiries.

Report Generation and Query by Example

One of the most burdensome jobs for the hospital personnel has been to collect the data necessary to publish the monthly and annual reports on the normal operation of the newborn intensive care unit. This can often mean culling the written records of the present and discharged patients to determine the essential information for reports. The information can be as important as the eventual outcome of the hospital treatment or as trivial as in which county the child's parents live. To eliminate, as much as possible, these frustrating hours of search for data, the report generator is being developed.

Currently, a few simple reports are being generated, such as the active patient report. The report, illustrated in Table 2, displays a table of patients currently being treated in the unit along with some pertinent information.

The patient stay summary and the admit/discharge summary which displays a breakdown of admissions and discharges for a specified period are additional reports. The monthly report is an extensive overview of the activity in the unit. This report is currently being developed.

There are certain questions the pediatric research team would like to ask of the collected set of facts available for all the patients. This might simply be to check a correlation of effects or check the response to a particular treatment. For this reason, the Query by Example routines are being designed. These routines, at this time, are still quite primitive. They allow the user to request the count and the records of all patients with a particular diagnosis or procedure. It does not, yet, allow for logical constructs of information. This capability is being developed.

Summary and Conclusions

In this paper, we have given a description and overview of the computerized information system that we constructed for the newborn intensive care unit of UNMH. There are several additions we hope to include in the system in the coming months. One feature would be the facility for real time monitoring where some data (blood pressure, temperature, and caloric intake) are taken directly from the infant's support system. This would require a small processor collecting data and periodically sending it to the larger system. Also, since many growth curves for normal children are fairly well understood, it would be nice to monitor changes in the patients' development, generating a warning, for example, of a too rapid cranial change, or when caloric intake is inappropriate to body

TABLE 2. THE ACTIVE PATIENT REPORT. THIS IS A LIST OF INFANTS CURRENTLY BEING TREATED IN THE NEWBORN INTENSIVE CARE UNIT.

ACTIVE PATIENTS

	ID	NAME	ADMIT DATE	UNIT
1	434097	SANDOVAL	71380	NBICU1
2	434786	SMITH	70480	NBICU1
3	434586	CASIAS	72480	NBICU1
4	434283	RODRIGUEZ	71980	NBICU1
5	434705	CHAVEZ	73080	NBICU2
6	412365	JOHNSON	70180	NBICU1
7	412268	GRIEGO	62280	NBICU2
8	434632	WEST	73180	NBICU1
9	433494	URIOSTE	62580	NBICU2
10	434604	ROY	72980	NBICU2
11	412460	JARAMILLO	72180	NBICU2

weight. We would also like to improve the QBE routines so that any pediatric researcher could enter the data system and ask any question pertinent to his or her current research.

We also feel there are specific "human engineering" issues left to be resolved to make the entire data system more comfortable for the medical staff. If the information system becomes difficult or cumbersome to use, it will be a failure simply because it will not be used to its fullest capacity, or worse still, will be abandoned. All these issues continue to concern us and will be reported on by our group in due course.

In conclusion, we feel the menu access, the daily procedure and diagnosis routines, and the query by example and report generation offer a general system for collection and manipulation of medium sized sets of medical data.

Copies of complete menus, as well as the full tables for diagnosis and procedures, are available from the authors for anyone wishing to examine the system further.

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