Henry Ford Hospital Medical Journal

Volume 32
Number 3 *Special Issue on Medical Computing*

Article 3

9-1984

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Henry Ford Hosp Med J
Vol 32, No 3, 1984

A Microcomputer Database in a Clinical Environment

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The practice of clinical medicine continually produces large quantities of information which must be organized, filed, and retrieved. It is sometimes necessary or helpful to rearrange, update, or extract portions of this information. Computers are extremely useful tools for performing data manipulations. In computer terminology, a systematic collection of information is termed a database, and programs designed to aid in processing such collections are database programs. Programs are sets of computer instructions which are referred to as software. The actual computer and its accessories are termed hardware. The combination of hardware and software form a computer system.

Even though many database programs exist, including some designed specifically to handle medical information, most medical information is processed by hand. A major reason for manual data processing is the enormous time and expense involved in designing computer systems that are complete enough to handle all the necessary types of information and yet simple enough to use without extensively training all persons who need to access the system.

In this article we evaluate the feasibility of using the relatively inexpensive technology of the microcomputer to solve a problem in the management of patient information in a clinical environment. Rather than discuss the steps involved in such a project as abstract concepts, the specific problem of a database for pediatric immunization records is presented. Many data management problems of similar size and complexity exist in other areas of medicine. The organization of approaches to the problem, software and hardware considerations will be applicable to other problems.

Steps in the evaluation process include:

- defining the problem to be solved
- describing the functions an ideal system would perform to solve the problem
- comparing the functional capabilities of existing computer software and hardware with the ideal system, and deciding whether the presumed functional capabilities of the software and hardware are sufficient to justify the effort of developing and testing a trial system
- developing a trial system
- testing the trial system against the ideal system
- deciding whether or not to implement an actual system

The Problem

The problem is that of maintaining immunization records for a large general pediatric clinic. Traditionally, an immunization record was kept in the patient's medical record, but the medical record frequently was not available in the clinic when the patient arrived for care. A common reason for this is the frequency with which patients came without an appointment. But whatever the reason, without access to the immunization record, the physician either had to guess which immunization the patient might need or schedule the youngster for a return appointment. The latter choice was inefficient and involved a risk that the child would not return for the appointment, thus missing the needed immunization.

The problem was particularly acute late each summer when forms documenting adequate immunizations had to be prepared before children could be enrolled in school. An index card file to maintain duplicate copies of immunization records was initiated to help with the retrieval problem. This file initially functioned relatively well, but within six years grew to contain over 20,000 records. As the work of updating, filing, and purging the records exceeded available staff support, the card file became less reliable. This manual system of maintaining immunization records was no longer feasible.

It was clear that the first function of any new system would be the rapid retrieval of immunization records. The second would be the inclusion of all immunization information needed for each patient. The Table lists the items of information which clinic physicians feel are necessary. In addition to immunization records, certain clinical data were included to allow physicians to complete many routine forms without having to request the entire medical record. This information required 450

Submitted for publication: March 27, 1984
Accepted for publication: July 25, 1984
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bytes of computer memory for storage. Based on previous clinic records, we estimated that 2,000 patients would be added to the system each year. Records for one year would therefore require approximately 900,000 bytes of storage. For an estimated useful life of five years, plus space for database programs, over five megabytes of online data storage were needed. Storage space was also needed for selection of data for reports and for possible rearrangements of data for other purposes.

TABLE

Information in Pediatric Immunization Database Record

A. Demographic Screen
   1. Medical record number — MRN (primary key to all records)
   2. Patient's name
   3. Date of birth
   4. Primary physician
   5. Name of parent or guardian
   6. Telephone number

B. Immunization screen
   1. Dates for 6 DPT* immunizations
   2. Dates for 6 OPV** immunizations
   3. Dates for 2 DT*** booster immunizations
   4. Dates for 3 TB**** tine tests
   5. Date for measles, mumps, rubella immunization

C. Clinical Information Screen
   1. Date of most recent examination
   2. Height
   3. Weight
   4. Blood pressure
   5. Date of most recent Hgb or HCT
   6. Most recent hemoglobin value
   7. Most recent hematocrit value
   8. Date of screening for sickle-cell disease
   9. Result of sickle-cell disease screening
   10. Date of most recent urinalysis
   11. Urinalysis (normal, abnormal)
   12. Date of most recent vision and hearing screenings
   13. Result of most recent vision screening
   14. Result of most recent hearing screening
   15. Date and result of blood lead level
   16. Date and result of rubella antibody titer
   17. Space for four lines of comments

*DPT = diphtheria, pertussis, tetanus
**OPV = oral polio vaccine
***DT = diphtheria, tetanus
****TB = tuberculosis

To be useful in handling the immunization records in the clinic, the operation of a microcomputer had to be simple enough to allow nurses and secretaries to use the system without extensive training. The security and privacy of the data also had to be ensured. Additionally, the system had to be resistant to operating problems caused by accidental or deliberate entry of incorrect commands.

An Ideal System

To solve the defined problem, the computer hardware had to store 10 megabytes of information and to retrieve any data within a minute or less. An ideal system allows the retrieval of records based on one or more criteria, such as all patients over one year of age who have not received three DPT (diptheria, pertussis, tetanus) immunizations.

An ideal system is easy for several persons to operate with minimum training. Thus, the system needs to be relatively self-explanatory or "user-friendly." One method for making computer systems easy to use is to have a series of menus, or lists of possible functions, which require the operator to press only a single key to start a new function or to proceed to the next menu. In addition, to ensure that only valid, correct information is entered into the system, the system screens the data as it is entered. For example, if a hematocrit value of more than 100% is entered, the system would detect this error and refuse the data.

It is desirable to have password protection so that unauthorized individuals are unable to access the data. Multiple levels of password protection are also desirable so that some users are able to view only the data, while others can view or alter data, and still others can enter and alter the entire system, if necessary. However, the addition of these features would be counterproductive if they slow the response of the system to a point where the staff often has to wait for the system to finish one function before another can be started.

An additional desirable feature includes the easy retrieval of several records. The best solution is for the person requesting records to be able to enter the primary search criteria, such as the medical record number, for several patients and be able to leave while the computer locates and prints the resulting records. To make this possible, the system must determine that a record with that medical record number exists in the database before the operator leaves the entry mode. While these features are standard for major database systems running on mainframe computers, they are not found often in programs designed for microcomputers.

The principal functions of any database system are finding, adding, changing, and deleting selected information within each record or an entire record. In addition, a system should generate a brief summary of such activities to provide a method for checking the accuracy of each entry or alteration.

Development of a Trial System

After reviewing the functional requirements of an ideal system, the budgetary constraints and existing hardware and software, we felt that a workable system was possible. We could find no software written specifically for our application, but several general purpose microcomputer database programs were available which had the major functions necessary for the project.

We chose dBASE-II (Ashton Tate, Culver City, California) as the software. The advantages of dBASE II are: 1) a relatively sophisticated programming language which allows developmental personnel the flexibility to design a user-friendly system with features that ensure data integrity and security; 2) use of a B+ indexing scheme which provides rapid record retrieval; 3) the capacity to store more than 65,000 records in a database file; and 4) the capability of operating on more than one brand of microcomputer.

A significant limitation of dBASE-II is that it allows a maximum of only 32 variables per database file. We were able to overcome this limit on variables by categorizing the variables into three groups: demographic, immunization, and clinical. These groups encompass the 44 variables identified for collection (Table). Three database files were created: a demographic file, an immunization file, and a clinical information file, each having the medical record number (MRN) as the key. Although the three files are independent, they are coordinated into a fully integrated system.

The trial system was started on an Apple II+ computer because dBASE-II would operate on this microcomputer and because the Apple II+ was widely used in our hospital when system development began. Another factor favoring the use of dBASE-II was its compatibility with the IBM PC/XT and other microcomputers. Development of the system began with two floppy disk drives for data and program storage. It soon became apparent, however, that the floppy disks could not be used as the primary storage medium because of the relatively slow operation and the need to change disks frequently. The Corvus hard disk, secured for developmental purposes, reduced data entry time by 40%, and both programs and data are now stored in a central location. The reduced operating time and ease of use were important considerations in making the system practical.

Operation of the Trial System

The database was designed to operate entirely in the interactive mode. That is, all procedures are executed when the user selects options from a menu and answers various prompts that appear on the screen. As with any database system, the user can add, change, inquire, and delete selected data elements or entire records. A hierarchy of on-line data entry screens was designed to expedite these procedures and to ensure the security and integrity of the database. Following is an example of the database operation.

The first screen in the hierarchy prompts the user for a password. If an invalid password is entered, a message appears stating this. The user is then returned to the password screen. Thus, no unauthorized persons can access the database. If a valid passward is entered, one of three menus is displayed: 1) the system manager menu which provides total access to the database as well as the capability to exit to native dBASE and the full operating system; 2) a full function menu with the same capabilities as the system manager but which cannot exit to native dBASE or to the operating system; and 3) a limited function menu from which the user can only inquire and report, but not alter, patient information. When one of these screens is displayed, the user can select the function that he wishes to execute.

After the user enters a code corresponding to a function, the entry screen for the MRN is displayed. For the initial patient entry (add function), any MRN that is entered is validated by a check-digit routine. If the MRN is invalid, a message appears on the screen stating this. The user is then asked if another MRN is to be entered. If the response is affirmative, the MRN screen is redisplayed. If not, the user is returned to the main menu. This sequence ensures the entry of only valid MRNs. When a valid MRN is entered, the demographic file is searched for its presence. If the MRN is not present, it is added automatically to the demographic, immunization, and clinical files. This procedure ensures that a record will exist in each of the three data files for each MRN to prevent problems which might occur from premature termination of data entry. When this procedure is completed, the entry screen for demographic data is displayed. After these data are entered, the user is queried if immunization data are to be entered. If the response is affirmative, the immunization data entry screen is displayed. If the response is negative, or after the data are entered, the user is then asked if clinical data are to be entered. After this, the user has the opportunity to repeat the entire procedure for another MRN without having to return to the main menu. When additions for all new patients are completed, the user is returned to the main menu. At this point, the user can select any other function and perform it repeatedly, or return to the appropriate menu. For the person whose password provides access to the full function menu or to the limited function menu, the exit returns the user to the password screen. The system manager can exit to the password screen, to native dBASE, or to the operating system.

Although the preceding discussion describes the function for adding new patients, the other functions (inquire, change, and delete) operate in a similar manner. Depending upon the function selected from the main menu, data for a patient (MRN) can be added, changed, or displayed only. After an MRN is entered, the demographic screen appears automatically. The user can then choose whether or not to have the immunization screen displayed. The same is true for the clinical screen. These functions can also be performed repeatedly without having to return to the main menu. In addition to these standard functions, a facility is provided on each of the three menus which generates a one-page summary report for any patient whose data reside in the database. The report can be used as a document on which changes to the patient data can be made and entered onto the database.

As previously indicated, the integrity of database values is an important issue. To reduce data entry errors, validation routines for many of the data elements are included with both the "add" and "change" functions. These involve edit criteria (eg, minimum and maximum values) on dates and other selected data elements. In the event that an invalid datum is entered for any of these elements, messages listing the possible valid values are displayed. The user is then prompted to reenter a value that adheres to the edit criteria.

Consideration was given also to the ease with which future modifications and enhancements could be made to the database. In view of this, the aforementioned functions and validation routines were written in "modular fashion." This means that many programs share common resources. If a routine is changed, the same change will appear in all functions which use that routine. This method of design facilitates the incorporation of enhancements into the system. New functions can be added with minimum difficulty since they are considered to be distinct modules. If any of the preexisting routines are needed by these programs, they can be utilized easily.

Evaluation of the Trial System

We found that our trial system fulfilled all major design objectives in terms of the amount of data the system could handle, user-friendliness, and rapid retrieval of data with data security, integrity, and resistance to tampering or accidental misdirection. The system was found to be cost-effective in terms of time and effort estimates with a projected payback time of less than two years.

Summary

We have assembled a clinically useful database with a commercial software package that is compatible with several brands of microcomputers. The system is easy to use with its menu-driven format, and it has the capacity to handle our estimated needs. The true cost-effectiveness of the system cannot be judged until it has been in actual operation for several years, but our estimates suggest that the system will soon pay for itself. Of greater importance, the guaranteed availability of immunization records and other information will enhance the quality of patient care by reducing the chances that pertinent information will be missed.

Many other problems in the management of patient information are similar in magnitude to the problem of unavailable immunization records. Our experience with immunization records suggests that many of these problems could be solved by using readily available microcomputer technology. A major advantage of microcomputers is the relatively low cost, hence, a rapid repayment in terms of savings in time and effort of personnel. There is also the potential to increase physician awareness of the advantages of computer data management.

There are also disadvantages and problems with these limited records. These accessories to the patient's medical record cannot be allowed to become a partial substitute for the medical record, and provisions for constantly updating and validating both are essential. Consideration must be given to the possibility that, in the future, it may be desirable to transfer the data accumulated in these small databases to a larger centralized patient database. The planning must also include a backup system so that if the system fails, the information will not be lost. With adequate planning, most of these problems can be surmounted and the benefits of such systems realized.