Building an Ambulatory Clinical Information System in a Family Practice Residency

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A programmable database may be implemented on a personal computer to manage the educational and clinical information needs of a family practice residency. Such a system can usefully and efficiently be based on the existing clinical encounter form. Data entry for a practice of 7500 patients with 20,000 visits per year requires little computer expertise and only 1 hour per day of clerical data entry time. The cost of such a system can be reduced to as low as $2500. A flexible, programmable database, rather than a commercial practice management system, is recommended as more efficient in accommodating continued development of strategies to meet the educational and clinical data needs in the family practice residency setting.

Recent changes in medical technology, the economic incentives of medical practice, and trends in professional liability litigation have all tended toward increased pressure on physicians to be able to measure what they do. Concurrent changes in information technology, particularly in the refinement of the personal computer, have made the development of local information systems not only possible but relatively cheap and easy as well. Residency training programs in family practice need to respond to this altered practice environment by preparing residents to deal with these new realities. In addition, residency programs themselves are under substantial pressure to document their residents' experience to ensure that residents have received adequate exposure to all parts of the recognized curriculum and to assist residents in the application for hospital privileges in this new medicolegal environment.

This paper describes a system developed to address these needs in a family practice residency and implemented over a 2-month period for a net cost of less than $5000. The system is called the Ambulatory Clinical Information System (ACIS) of the Department of Family and Community Medicine of the Milton S. Hershey Medical Center.

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The clinical work of the department is currently carried out in a new and separate building, the University Physicians' Center, which houses the ambulatory component of several other specialties as well. The medical center employs mainframe computer technology to implement a centralized computer scheduling system and billing system linking all clinical departments, but neither of these systems provides data of immediate clinical or educational value to physicians. Rather than wait for the existing technology to be supplemented or modified to accommodate the practical information needs of the department, the Department of Family and Community Medicine made the decision to install a separate personal computer-based clinical information system in the Family Practice Center (FPC). Departmental constraints, mainly fiscal, required that the system be flexible, inexpensive, and parsimonious in maintenance and data-entry time.

The personal computer hardware selected was a clone of an IBM PC AT model microcomputer running a 80286 microprocessor at 12 MHz with a 40-megabyte hard disk. This system was purchased by mail order at a cost of $1800, which included a monochrome monitor and dot-matrix printer as well. The software selected was a fourth-generation, programmable, relational database called "ZIM,"* with which the author had previous experience. The developer's full version of this program currently costs $2000, but the application described below is available from the author in a compiled run-time version for about

* *ZIM is a registered trademark of Zanthe Information, Inc, 1200-38 Antares Drive, Nepean, Ontario K2E 7V2, 800-267-9972.*

$500. This software is also available in multiuser versions. Backup of the system data is carried out using a relatively slow, but inexpensive, 1200-baud modem connection to an independent personal computer in the precepting area of the Family Practice Center using the pcAnywhere III† remote file transfer program during weekend hours.

The design of the information system is focused strategically on the routine encounter form, which had previously been used solely for fiscal purposes. This form contained much of the important clinical data, namely, patient name and number, physician name, visit date, all diagnoses, all laboratory tests and x-ray examinations ordered, all office laboratory tests done, all immunizations and injectable medications given, and finally all office procedures done in the course of the visit. As the current form already existed in triplicate, it was possible to divert a separate copy solely to the purpose of data entry in the ACIS.

The FPC takes care of a patient population of about 7500 and approximately 20,000 visits per year. Thus, on a daily basis, there are about 40 to 70 encounter forms to be processed. The system has also been designed to capture data from patient registration sheets for new patients, averaging from 0 to 10 such forms per day. The department anticipated that a secretary with no special computer training could type the necessary data in at the computer screen in less than 1 hour a day; this estimate has proven correct over the first 6 months of operation.

The first step in setting up the ACIS was to transfer by modem the active patient list and corresponding demographic data from the existing practice database on the mainframe system. The file, named PATIENTS, containing the master list of patients and identifying numbers (ID), is the hub of the entire clinical information system. The properties of the relational database allow the database design to conform to the logical sequence of clinical operations in the center (Figure 1).

Figure 1 illustrates the relationships between the major classes of data that are currently being tracked in the ACIS. The primary block of data is the master patient list (PATIENTS). This data set is further characterized by several supporting files for specific data subsets, such as extended demographic data (for research purposes), household and family sets, initial clinical data abstracts (INTAKES), and health maintenance flow chart data (HMFS).

As the ZIM database program involves a user-defined interface, an outline of the basic programming steps is appropriate here. There are three essential components to be designed for any data-capturing process. First, using a basic prototype such as an encounter form, one selects the pieces of information desired for permanent storage and creates a file with an individual, named field of a specified length for each piece of information to be stored. For example, the file PATIENTS has the following fields:

1	ID	8 digits (this is a unique number)
2	NAME	25 characters (format LastName FirstName)
3	SEX	1 character
4	RACE	1 character
5	DOB	8 digits (Date of Birth; format 19890101)
6	MD	15 characters (Primary Physician)
7	ADDR1	20 characters (first line of address)
8	ADDR2	20 characters (second line of address)
9	CITY	20 characters
10	ZIP	5 digits
11	PHONE	10 digits
12	AGE	3 digits 1 decimal (a "calculated" field based on DOB)
13	DOE	8 digits (Date of Entry)

The second step is to create a data-entry form for the computer screen that has blank lines exactly matching the above fields along with labels to identify each blank. This form is the only part of the database program with which the data-entry person interacts.

The third and final step is to use the intrinsic programming language of the database to carry out repeated sequences of instructions. The following is the basic instruction logic:

1. Display the appropriate form on the computer screen and allow the clerk to enter data.
2. Check the data on the screen for validity when the clerk indicates that he or she is done.
3. If the data are valid, transfer the data from the form to the appropriate database file for permanent storage and indexing, then redisplay a blank form for the next set of data. If the data are not valid, beep, and redisplay the form with the cursor at the position of the invalid data so the clerk may edit and correct the data, then transfer the data to the permanent file.
4. If no new data are entered, go back to the main menu.

The other major use of the programming language and the capacity to create forms is to design system menus to allow personnel to select specific functions by merely pressing a number or letter. The basic menu offered to the staff in the FPC at this time includes the following functions: finding a patient's data by number, finding a patient's data by name, updating patient addresses and telephone information, and updating tickler files. In this way the system can be made very user friendly. Menus can also be used to restrict certain classes of users from manipulating specific data subsets to avoid corruption of the data.

† pcAnywhere III is a registered trademark of Dynamic Microprocessor Associates, Inc, 60 E 42nd St, New York, NY 10165, 212-687-7115.

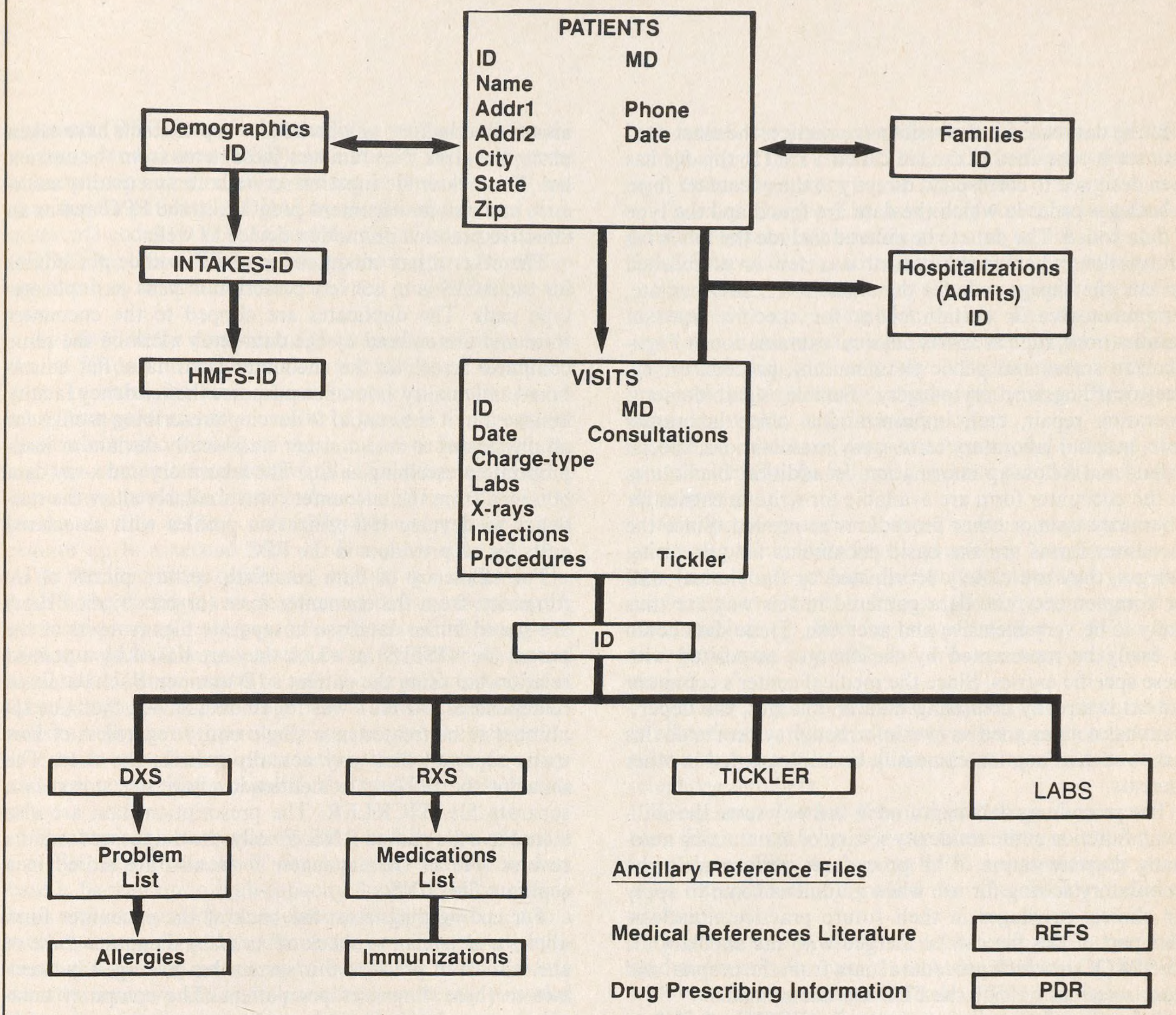

Figure 1. Schematic of database design for a system designed to address the needs of a family practice residency, called the Ambulatory Clinical Information System. ID—patient identification number; PATIENTS—master patient list; NODATA—log of incomplete or missing patient information; ADDR1—first line of street address; ADDR2—second line of street address; VISITS—master file of patient encounter data; ADMITS—master file of inpatient admissions; INTAKES—summary of past medical history file; HMFS—health maintenance flow sheet data file; DXS—patient diagnosis master file; DXDAT—master file of accepted diagnostic codes; RXS—patient prescription information master file; RESPROC—residents' procedural documentation master file; TICKLER—log of patient recall data; IDDATA—master file of authorized user passwords; MDS—master list of department physicians; LABS—master file of laboratory test results; REFS—selected medical literature abstracts; and PDR—prescribing information for selected drugs.

In the database for the residency practice, the most used data set is contained in the file called VISITS; this file has been designed to correspond directly to the encounter form in both the order in which the data are found and the type of data coded. The data to be entered include the following information: whether the patient is a new or established patient, the charge code for that visit (brief, intermediate, comprehensive, or certain codes for specific types of examinations, such as sports physical examination or Papanicolaou smear and pelvic examination), procedures (eg, electrocardiogram, cryosurgery, flexible sigmoidoscopy, laceration repair, etc), immunizations, office laboratory tests, hospital laboratory tests, x-ray examinations, special orders, and follow-up information. In addition, blank lines on the encounter form are available for write-in entries for laboratory tests or other procedures as needed. Since the encounter forms are the basic documents for generating charges, they are closely scrutinized by the clerical staff for completeness; the data gathered in this way are thus likely to be very inclusive and accurate. These data could as easily be represented by the charges associated with these specific entries. Since the medical center's computer system is already compiling data on charges, the department has not designed its own information system to do this task, but this function can easily be implemented in other contexts.

The procedures data captured in this way serve the additional function in the residency setting of maintaining automatic documentation of all procedures performed in the ambulatory setting for use when graduates come to apply for clinical privileges in their future practice situations. This part of this file can be merged with the ancillary file RESPROC in which procedural data from the hospital and other rotations outside the FPC are maintained.

A further elaboration on the basic VISITS set of data consists of the special subset of patient visits to the FPC or the emergency room that result in an in-patient admission. These data are stored in a separate file named ADMITS, which contains data abstracted from the patient's brief discharge summary at the time of discharge.

The FPC is currently in the process of further modifying both the encounter form and the prescription forms to facilitate entry of other key pieces of clinical data. Additional blanks will be put in the encounter form to allow physicians to check a box to request for automatic patient recalls (a tickler file). On a blank line next to this box, the physician records the indication (eg, follow-up of chronic diseases, such as hypertension or diabetes, or of abnormal laboratory test results, such as an abnormal Papanicolaou smear) for the recall and the interval at which the recall is desired; the ACIS will automatically generate a postcard to the patient at the specified date and the physician will be sent a reminder as well. The provider then returns his or her printout on a monthly basis to the data entry clerk with annotations indicating which follow-up contacts have taken place; the clerk then removes these items from the current list. This tickler file function serves both as a quality assurance and risk management program in the FPC and as an effective practice promotion device as well.

The other minor modification of FPC office procedures for the ACIS is to convert prescription pads to duplicate-type pads. The duplicates are clipped to the encounter form and are entered by the data-entry clerk on the same computer screen as the encounter form data. For educational and quality assurance purposes the residency faculty believe that it is essential to develop prescribing profiles for all physicians to detect either statistically deviant or inappropriate prescribing habits. The laboratory and x-ray data obtained from the encounter form similarly allow the residency to develop test-utilization profiles with associated costs for all providers in the FPC.

For efficiency of data retrieval, certain pieces of information from the encounter form (or prescription slips) are stored in the database in separate files (subsets of the parent file VISITS) to which they are linked by a defined relationship using the patient's ID number. Such database relationships provide a way for all data having the same ID number to be treated as a single entity regardless of how many separate files may actually contain the data. The data for the tickler file mentioned above are stored in a separate file, TICKLER. The prescription data are also stored in a file named RXS. Finally, the diagnoses from the reverse side of the encounter form also are stored in a separate file, DXS.

For coding diagnoses, the back of the encounter form allows a physician to check off as many diagnoses as he or she wishes; in practice this system has averaged between two to three diagnoses per patient. The computer data-entry screen has been designed to accommodate up to five diagnoses. There is also a limit of five to the number of prescriptions that can be recorded.

One of the advantages of a programmable relational database is that it allows the practice to create a defined routine to select certain diagnosis codes from the DXS file for automatic inclusion in a patient problem list. Similarly, predefined criteria can be used to select certain types of medication from the RXS file for automatic inclusion in the chronic medications list. This process can be automated for either individual use at the terminal or for a batch-processing operation for the entire practice by setting up the program to execute unattended over periods of inactivity (eg, nights or weekends). In terms of the database structure, these problem list and medication list files are stepchildren of the DXS and RXS file, to which they are also linked by the patient's ID number.

The department has also established a number of utility or help files for use with the system. Reference files exist for user on-line searching of selected medical literature abstracts (REFS) and for prescribing information for the common medications (PDR). In addition, certain internal reference files exist, such as the log of bad or incomplete data sets for patients (NODATA), the list of standard diagnoses and codes (DXDAT), and the list of valid passwords (IDDATA); these data sets are for the purpose of validating data, as described below, and are transparent to the user.

At this time the department plans further refinements to the ACIS only to accommodate the results of laboratory data. In those facilities where laboratory results are already computer stored, it should be possible to arrange for direct electronic transfer of these data. For facilities lacking any computerized record of laboratory test results, these data would also have to be entered by a data-entry person. In this setting, capturing laboratory data might require up to a second hour of data-entry time per day. After the laboratory results are entered in a separate file, LABS, the database can be programmed to automatically generate warning messages to the physician indicating out-of-range results; the system can be set up either to respond to all out-of-range results or only to a preselected range of special high-risk out-of-range results. All out-of-range results can then be automatically appended to the tickler file. It remains to be determined whether this enhanced quality-assurance capability will justify the additional cost of data entry.

This clinical information system was fully operational in the FPC after 6 weeks of development. The entire data base is backed up to high-capacity floppy disks on a daily basis and on a weekly basis electronically transferred to a second computer within the center, which allows physicians and nursing personnel to access the system's data directly. Security and confidentiality is currently provided through a simple password system. Original data are entered only by a single data-entry person.

A critical aspect to the development of any clinical information system is the assurance of data validity. In this system the accuracy of the data is verified by a combination of the following programming routines:

Patient identification number. Every time the data-entry clerk enters a patient identification number (ID), the program scans the master patient list for the name associated with that number, lists it, and inquires whether this patient is the one wanted. If the clerk types "no," the program prompts her to enter the identification number again; if the clerk types "yes," an entry is made to the NODATA log file for subsequent verification and data entry is allowed to continue.

Diagnosis codes. For each diagnosis entered on the computer's data-entry screen, the program performs a check against a specific file (DXDAT) containing the master list of accepted diagnostic codes for the practice. If the code is not found, the program redisplays the data-entry screen and positions the cursor at the invalid code entry for correction before final entry to the DXS file.

Types of charges. The data-entry screen is programmed to allow only certain specific codes (ie, br, int, and com for brief, intermediate, and comprehensive, respectively).

Physicians. The data-entry screen is programmed to recognize only certain physician initials. The data-entry person types in the appropriate initials; the program validates them and then automatically converts them to the full name of the physician for display of the data. This system saves keystrokes and data-entry time.

After 6 months of implementation, the residency program has made the following specific practical uses of the data system:

Routine chart audits. Every 2 weeks a program is run to select all patient visits for the preceding 2 weeks sorted by physician. These lists are distributed to the faculty supervisor for these residents to have a specified percentage of the charts pulled (eg, 100% for 1st-year residents, 25% for 2nd-year residents, and 10% for 3rd-year residents) and reviewed.

Provider panels of patients. Quarterly, the updated lists of all patients assigned to each provider are printed out and distributed; these lists include patient ages, addresses, and telephone numbers.

X-ray examination lists for radiology conference review. Each week a list of x-ray examinations ordered during the preceding week in the FPC is automatically generated; these films are pulled for the weekly radiology conference.

Obstetric lists. A list of active obstetric patients is generated automatically every 2 weeks by retrieving all patients with visits having a diagnosis code of V22.1 (prenatal care) or V22.2 (diagnosis of pregnancy) but not V24.2 (postpartum care). This list is referred to the faculty member in charge of the obstetric service for review of charts.

Hospital admission/discharge lists. Practice planning and analysis is facilitated by monthly summaries of inpatient hospital activity for all providers.

Patient telephone and address information. Communication with patients by both nursing staff and physicians has been facilitated by making it easier to look up this information without having to have the chart available.

Clinical inquiries and research. The ACIS provides the capability of easily linking patient demographic data with diagnoses, health care utilization, treatments, and laboratory results. This facilitates both informal clinical projects, which is a required component of the residency program for residents, and formal research investigations for faculty.

Procedural documentation. These data are useful both for designing the residency procedural curriculum and for applying for clinical privileges in practice.

Resident evaluations. The database has been adapted to accommodate the results of standard residency evaluation forms (both faculty evaluations of residents and resident evaluations of faculty). Printouts of evaluations sorted chronologically by resident makes it easier to see trends in resident performance and helps to ensure that weaknesses have been addressed. In addition, it facilitates the process of writing succinct and pointed letters of recommendation for residents.

Response to the installation of this system in the residency has been very favorable. In the early stages, however, it is clear that the faculty and nurses find the system more practically useful than the residents in accomplishing their routine tasks—most frequently for the purpose of contacting patients without having to retrieve the chart. The faculty have begun to make use the information system for a variety of research projects. The residents have responded very well to being provided with clinical summaries of their patient care experiences but have not spent much time interacting directly with the ACIS at the terminal.

A review of the expenses incurred in operating the ACIS for the first 6 months has identified the following costs:

Hardware

$1800—IBM PC AT clone (80286 microprocessor, 12-MHz 640K RAM, 40 MB-hard disk, monochrome monitor, dot-matrix printer (operating system software included)

$89—Internal Hayes-compatible 1200-baud modem for communications

$300—Extra 30-MB hard-disk added to existing residency computer solely for the purpose of backing up the ACIS files

Software

$2000—Initial cost of the complete developer's version of the ZIM database

$79—pcAnywhere III file transfer program

Personnel

$2640—.12 FTE data entry clerk, 1 hour per day (including 10 minutes daily for backing up the data to floppy disks)

($2640)—(Cost of projecting expansion of data entry to 2 hours per day)

$4000—.05 FTE faculty time for development, maintenance, and refinement

Supplies

$60—High-density 1.2 MB diskettes for backup

$60—2 cartons continuous printer paper

$30—2 replacement ribbons for printer

The design of this system enabled the department to keep the initial outlay for hardware quite low, approximately $2200. It was a major advantage that the author had already owned and mastered the ZIM database program. For similar efficiency and cost savings, the choice of software should be made on the basis of what software and expertise is already available to an institution. Many other commercial database packages will perform the functions described above as well.

The single largest cost of the system currently is the approximately 5% of the author's time devoted to this project. Since computer applications in primary care are the author's major research interest, this cost does not really represent an additional burden to the department. For a continuously developing project like an ACIS to be successful, it is essential that an institution have at least one person with the personal interest and commitment to the project to nurse it through the inevitable early bugs. In settings where such a resource person is lacking, an alternative is to obtain a compiled run-time version of a proven, existing system. A compiled application costs less than the developer's full version of the database, but will require the purchase of consulting time (at approximately $25 to $50 per hour) from the developer to modify the system in the future. In many contexts, this trade-off can be cost efficient.

It appears highly likely that this information system saves the department money in certain ways, but there are no available data to substantiate this. Savings would be expected primarily in reduced faculty time required to analyze resident education and clinical experience. Any time that appropriate feedback can be given to a resident without specifically having to pull and manually review a chart saves faculty time. Furthermore, it is anticipated that the use of the tickler system and a system of regular recalls for preventive health services can both generate direct patient care revenues and promote the practice generally. A major goal of further system development will be to try to generate data adequate to confirm or refute these hypotheses.

After a review of the initial 6 months' experience, the department has concluded that the ACIS has effectively provided for the residency's informational needs at an affordable price over a short period without running into conflicts with the medical center's existing mainframe technology. Since its inception the system has dramatically improved faculty knowledge of residents' clinical experience in the residency, and has improved certain aspects of clinical care such as follow-up. The use of a flexible, programmable database has met all the data needs identified by the department. The initial investment of time to learn the essential program logic has been more than compensated by the ability to adapt the system to the department's changing needs rather than have to wait for periodic updates from commercial vendors of practice management systems. The essential task that remains to be done is to use the system to confirm the presumed cost effectiveness of this solution to a residency's informational needs.