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Development of a Nephrology and Hypertension Information System

Francis Dumler, MD,* Gerard Zasuwa, BA,* and Nathan W. Levin, MD*

This article describes our experience in the development and implementation of a computerized information system specifically designed for a Division of Nephrology and Hypertension. Specific issues related to planning and implementation are discussed, and potential pitfalls in setting up such a system are addressed. The combination of a mainframe and a minicomputer as integral parts of the system and the development of peripheral support in specific applications using a personal microcomputer are also described. The important area of user/computer interface and of user motivation is discussed in the light of the experience acquired while implementing the current system.

The Division of Nephrology and Hypertension of Henry Ford Hospital serves five separate locations with an annual census of over 52,000 patient visits to the outpatient clinics, dialysis and transplantation programs. The volume of clinical data generated by this patient population is very large and is capable of being used for direct patient care, analysis of treatment trends, patient compliance, clinical research, and a variety of administrative tasks, including use of key indicators for quality evaluation, material utilization, productivity statistics, scheduling and billing. The purpose of this paper is to describe our experience with the implementation of a computer system for a clinical nephrology setting. Two approaches will be discussed: 1) the development of a combined mainframe-minicomputer system capable of maintaining and managing a substantial database and 2) the use of microcomputers for individually tailored applications.

Objectives

For the user the objectives of the system were:

1. to facilitate the planning, monitoring and control of individual treatment programs.
2. to facilitate the division's administrative operations.
3. to support the division's clinical research activities.
4. to provide a friendly user/system interaction.
5. to encourage the interest of physicians in computer-assisted delivery of health care.

From the data processing point of view, the objectives of the system were:

1. to provide up-to-date, comprehensive and accurate information.
2. to allow local input and output.
3. to allow timely response and turn-around time.
4. to provide high-resolution graphics and text outputs.
5. to provide statistical capabilities for standard and ad hoc reports.
6. to have reasonable flexibility for further changes and improvements and sufficient expansion potential.

To manage the large clinical database requirements and at the same time provide customized subprograms and interactive graphics analyses for individual patients, a combination of a mainframe IBM computer (series 3081) and a minicomputer system (Clinical Computing LTD, UK) was chosen. This configuration was chosen because it allows independent modifications of screens, graphics and database programs. In addition, as individual members of the division designed and implemented clinical or educational applications on personal microcomputers, this configuration allows programs to be incorporated into the minicomputer system for routine use.

Implementation

Implementation of the system was carried out in three phases: 1) patient care subsystem, 2) laboratory results subsystem, and 3) ad hoc analyses and reporting.
Patient care subsystem
The most important aspect of this phase was the definition of the patient care elements required in the database. All medical and paramedical personnel were interviewed regarding their opinions and needs. The lists of the various elements considered to be of relevance were reviewed multiple times to ensure that all data deemed necessary were included, that superfluous elements were not incorporated, and that duplications did not occur. The input of system analysts and programmers was critical in order to maintain a practical and manageable system. When the database was finalized, the format to be used for input was extensively discussed with physicians and paramedical personnel. The designed input forms, which doubled as part of the medical record, were field-tested and finalized only after approval of the potential users. Multiple revisions were often necessary after experience had been gained with field use. The patient care subsystem currently includes demographic data, social history, problem and diagnoses lists, dialysis access history, routine testing schedule, medication history, dialysis treatment flowsheets, renal transplant donor and recipient workup, outpatient nephrology, hypertension and transplant clinical visit data, and patient death data.

Laboratory results subsystem
In addition to the above procedures, it was also necessary to establish a data transfer system from the Department of Pathology computer system to the mainframe IBM computer. Laboratory information including hematology and multichannel chemistry profiles, urinalysis, renal function tests, and drug serum concentrations, among others, are routinely entered and stored. Laboratory results can then be retrieved for each patient in various formats, i.e., by date, individual type, class or group.

Ad hoc analyses and reporting
This phase required intense interaction between end users, analysts and programmers. It was essential to allow for flexibility in the generation of specific reports sorted or grouped by a wide range of elements. A clear understanding of the physician's need by the analysts and programmers was essential for this purpose, and this required much mutual education. Again, the format of the output reports was extensively tested prior to implementation. The use of exception analysis in various areas was implemented to improve patient care through early identification of trends and the ability to generate rapidly up-to-date status reports.

Hardware/Software Requirements
The Nephrology Information System mainframe unit is an IBM 3081 running under the MVS Operating System, utilizing CICS as the telecommunication handler, DL/1 as the database management system. Custom COBOL programs for batch report generation, SAS as the online ad hoc report generator, and SAS/SAS Graph for statistical analyses and graphics reports. All subsystems were custom designed and developed using IBM's Application Development System-Patient Care System. User-friendliness has been accomplished by maximum utilization of the light pen for data retrieval to eliminate needless typing or the memorization of a command drive interface. The miniframe unit is a DEC System Model PDP 11/23 operating under RSX 11M and capable of running the Clinical Computing Nephrology System as well as programs written by members of the Division of Nephrology and Hypertension using a C language compiler.

Discussion
The physicians in the Division of Nephrology and Hypertension had no prior experience in the use of computers at the time the decision for implementation of an information system was made. Planning was initiated in January of 1981, and initial studies on feasibility, requirements and system design were completed by mid-1981. These implementation phases demonstrated to us the critical importance of close communication between those designing and programming the system and those using it. During the initial development, much time and effort was unproductive. Although the hardware/software systems described in methods were very adequate, the final product did not satisfy specific physician needs. Analysis of the situation indicated that system analysts were working in partial isolation from the end users. The creation of a steering committee consisting of physicians, nursing and administrative personnel, system analysts and programmers was critical in opening lines of communication between all groups. The system has had definite impact on direct patient care in two areas: 1) by providing on-line access to demographic data, it avoids the time spent in retrieval of the medical record for addresses, telephone numbers, information about relatives, social services, etc, and 2) by providing on-line data about patients' medication histories, it improves prescription patterns, makes it easier to recognize potential drug interactions, and facilitates over-the-phone prescriptions. The recent addition of the laboratory subsystem will add important information for patient care. Tracking of blood pressure readings has also assisted in patient care. However, the practical impact of the longitudinal assessment of patient diagnoses and problem lists needs to be established.

The system has been very successful in facilitating the evaluation and implementation of various treatment programs particularly in the area of dialysis (1-3). It is easy to analyze data for individual patients, individual dialysis units and their respective shifts, or all units
combined. Information regarding types and frequency of complications, effect of treatment on blood pressure, predialysis BUN concentrations, weight gains between dialysis, number of infectious episodes, and morbidity and mortality data, among others, are immediately available for analysis. Summary reports are made for individual patients, shifts or units and are used for evaluation of current treatment programs and for assessment of new therapeutic modalities. Similar data management has proved to be of great assistance in evaluation and improvement of the overall operation of the division. Census data, better scheduling of personnel time, material management and tracking of extra billing procedures are some of the advantages of the system.

The system has been invaluable in support of clinical research activities of the division. Retrieval of patient data for long-term follow-up of patients has made it possible to carry out longitudinal clinical research projects that otherwise may not have been feasible (3,4). The system simplifies the retrieval of data for large-scale projects and facilitates prompt statistical analyses. Furthermore, by allowing the test of hypotheses with the current database, prospective study designs are easier to design and maximize. The clear advantage conferred by the system in this area has served as a catalyst for clinical research activities (1-4).

Implementation of the information system generated an interest in computers within the division. Several members acquired personal microcomputers and apply their personal interests and experience to various projects. Programs have been written for the use of urea kinetic modeling in the prescription of hemodialysis and for the measurement of protein catabolic rates in critically ill patients (5). A program for heparin dosing during hemodialysis using pharmacokinetic principles, and a mineral analysis program is also available. The area of computer-assisted diagnosis is of current interest, for example, a program evaluating the differential diagnosis of an increase in serum creatinine occurring in patients after renal transplantation (6).

The educational potential for computers in nephrology and hypertension is currently under consideration with resident physicians, paramedical personnel, and patients as potential users. As more microcomputer-based programs written by members of the division are predicted, we have started centralizing this activity to ensure easy access for all. All submitted microcomputer programs are implemented on the minicomputer system using a C language compiler and accessed through a menu system.

The basic data processing objectives have been adequately met in a timely fashion. However, as experience accumulates, current trapping methods for error range values may need to be reassessed. Local input and output has been implemented without difficulties. Turn-around time for data is adequate; however, as the database increases, a faster communication protocol may be required. Both standard and ad hoc reports are delivered on schedule or within a reasonable time following a special request. The statistical capabilities of the system are superb, as its own statistical subroutines are complemented by access to the SAS statistics package operating under TSO. The Clinical Computing LTD miniframe system allows immediate data retrieval of active files and easy formatting of output screens to satisfy specific needs. Furthermore, its most significant ability allows the creation of multiple graphic representations of tabular data over a time course. Data can be examined at intervals ranging from days to years and in various combinations of up to nine variables at any given time. This facilitates the identification of trends and correlations.

Several difficulties must be overcome when planning a system such as the one described here. There are several trade-offs to consider in its implementation, and the size of the database is a prime consideration. In our case this was the key factor in selecting a mainframe-based system as opposed to a miniframe configuration. Since the mainframe computer was already available in the institution, this hardware cost was calculated only on the basis of usage time and storage space. The nature of the database is important because most system analysts are used to working with financial or production information and do not understand the need for long-term backing of all individual patient data and the multiple combinations of data that the clinician may require for patient care, management and research. As indicated previously, it is critical to have very close communication between physician, paramedical personnel, administration and the data management team. Extensive review of input and output formats by the end users is also very important in achieving a smooth operation and adequate turn-around times. Efficiency in data input required that one individual be assigned all input responsibilities at each of the various locations.

The responsibility for output and ad hoc reports as well as the overall supervision of the miniframe components and its link to the mainframe system has also been placed on a single individual who has been extensively involved in the planning and implementation of the system. The combination of hardware, software and personnel may be expensive. However, the productivity of these individuals is high, and the overall gains in better management of the affairs of the division should offset this expense. For example, the cost of the two full-time employees dedicated to the nephrology information system has been offset by a 10% increase in direct patient care time at no extra cost and by improved billing for medications administered during dialysis, resulting in a $6,400.00 monthly increase in chargeable
items and a decrease in billing personnel time of 50%. The value in terms of better patient care and increased clinical research activity is not as easily quantitated. Strong belief by the leadership in the need and in the success of the system is also very important to the successful implementation of the current system. The one area of disappointment has been physician participation. All those physicians who were supportive and interested from the beginning continue to be so. Those who were less than enthusiastic have shown little change, and those that were hostile have learned to live with the system. This difficulty is not a failure of the system per se, and is being currently addressed by a combination of learning while using, demonstration of the friendliness of the system and peer pressure. However, with time and increasing evidence of the capabilities of the system, we hope to make new converts.

A multiple database system in which patient treatment modalities change over time presents special problems. As the database grows in size, the necessity to store old data becomes apparent. In order to maintain an on-line treatment modality history, a separate section of the database such as dates of dialysis, modality, transplantation and expiration or transfer are self-maintained by the software and not subject to storage in archives. A dynamic system as described here must be able to fill the needs of different medical specialties which share the same interest but not the same immediate concerns. Hard-coded reports may not be able to satisfy the needs of everyone. Flexible, synoptic reports that contain static and time-related variables should allow individual users to achieve the maximum potential of computer use.

In summary, the described hardware/software systems we use provide very adequate and powerful tools for the development of a clinical information system. The critical factor is the close cooperation between system analysts and physician users in the development of a configuration specifically tailored to the particular needs of a given nephrology and hypertension practice. Physician motivation is a key element for the optimal use of a clinical information system.

References