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A Large-Scale Professionally Oriented Medical Information System — Five Years Later

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Success is the word used most often to describe El Camino Hospital's computerized medical information system. Operational since 1972, the system has gained total support from virtually all hospital personnel. Physicians, nurses, and administrative people use the system routinely as part of their day-to-day activities. HEW-sponsored studies have heralded the system for its impact on improving patient care and containing costs. The following paper is an overview of the system from installation to the present. It tells of the vast information available to hospital professionals through simple lightpen selections on a CRT screen, how it handles most manual activities, how it reduces errors, and how it replaces the nurses' Kardex files. Automated systems technology is vital to the future of health care, and it is a valuable tool for enhancing the quality of patient care and improving the use of labor resources. This paper further gives an important insight into other benefits offered to all hospitals by the advent of systems such as the one at El Camino.

INTRODUCTION

In December 1971, the Admissions Office at El Camino Hospital was brought on-line as the first step in installing a computerized medical information system. Nine months later the entire hospital, with few exceptions, had been converted to the system.

Almost three years later, in August 1974, secret ballots were cast by El Camino Hospital's professional and administrative staffs. The reason: to determine whether the hospital should retain the medical information system it had initially installed as a development project. The results were overwhelmingly positive. Those in favor: 94% of the nursing staff; the administrative and technical staffs; a majority of the 300 physicians.

With this vote of confidence, El Camino Hospital had firmly established for itself that the medical information system was a clinically valuable resource. There was also considerable interest in exploring many new ideas and uses for the Medical Informa-

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tion System (MIS). Shortly thereafter, El Camino Hospital signed a second contract with the system's developer, Technicon Medical Information Systems Corp., Mountain View, California.[1]

PREINSTALLATION

Late in 1970, the National Center for Health Services Research and Development, a department of HEW, issued requests for proposals for a comprehensive study of a real-time hospital-wide information handling system. This major action was a result of high-level HEW concern about skyrocketing national health care costs, declining productivity in hospitals, and an increasing necessity for accountability over Medicare, Medicaid, and other government-sponsored insurance programs. In June 1971, after an extensive review of some 18 systems in various stages of development in hospitals across the nation, El Camino Hospital was selected as the evaluation and demonstration site for a four-year, $1.2 million study to be conducted in conjunction with Battelle Columbus Laboratories, Columbus, Ohio. The results of that study were made available in December 1975.[2] Essentially, the study heralded MIS as providing a "significant improvement in health care delivery" and "indicated savings in excess of the system's costs." A follow-along study, which determined the economics of MIS internal to the hospital, was released in January 1977.[3] A further study will compare El Camino's experience with six similar California hospitals without computer systems to determine if the MIS made a significant difference in lowering costs and stemming inflation when compared to these other hospitals.

What were the circumstances of the El Camino experience that made this venture work, while many similar attempts in other hospitals failed or peaked out below expectations? The answer rests in a point of theory: basically, there are cost-rising applications of technology and cost-reducing applications. In order for the application of automation to a health care environment to be successful, it has to produce bottom-line savings while simultaneously providing more benefits or advantages in the delivery of health care than a previous approach. Supporting this theory is a statement by Martin S. Feldstein[4]: ". . . new and sophisticated equipment has been a crucial factor in rising medical care outlays. New technology (automation) in medicine, unlike that in other industries, has unfortunately tended, on the whole, to be cost-rising rather than cost-saving. The initial expense for the new equipment and its installation is often high . . . . Once the equipment is in place, operating costs, including the cost of the highly trained personnel usually required, can be substantial."

Cost-lowering technologies are oriented toward spreading the benefits and costs over all hospital patients and replacing as much of the high cost associated with their care (labor) with capital equipment. This also deters the effects of inflation to a substantial degree.

It is well established that patient care is very labor-intensive and constitutes approximately 60% of the total operating budget for a typical short-term acute community-type hospital, like El Camino. What is not well known is that as much as 25 to 35% of nursing service personnel time, both professional and administrative, is spent in manual information processing (form filling, record keeping, etc.). One look at a nursing station immediately before shift change will provide convincing proof that a tremendous amount of information moves around daily in a hospital. To handle this paperwork, hospitals in increasing numbers are using high-cost professional help. On a national scale, this is causing health care costs to skyrocket and productivity to decline.

USER INTERFACE

A basic premise of this system design is that the individual generating the data should be the one to communicate the data to the computer system. This is particularly apparent for the physicians and nurses as there is no data terminal operator to interface in their stead. This concept has made it possible to open many new areas of the system for these users.[5]

The medical staff at El Camino Hospital is composed of 307 active physicians, 49 associate staff members, and 154 courtesy staff members. El Camino is a publicly owned self-supporting general hospital, and does not have internship or residency programs.

There are 60 computer terminals located throughout the hospital with two on most nursing units, the others distributed as need dictates. These terminals, called VMTs (video matrix terminals), consist of a television screen, keyboard, lightpen, and a high-speed multiprinter for producing "hard copies" of reports.

At El Camino the "lightpen" selection capability has made it possible for the nurses and physicians to interface directly with the system. The lightpen provides a convenient and quick way to use the system, with only occasional need to use the keyboard.

To select items on the TV screen display, a user merely points the lightpen at the desired word or phrase and presses a button on the electronic lightpen. By making a series of selections, a physician can rapidly and accurately compose medical orders, review patient data or test results, or consult a wide variety of medical reference information from a library of antibiotic sensitivity surveys, lab results, interpretation aids, current surgical abstracts, antibiotic ordering information, hematology programs, etc. In total, over 13 areas of cumulative or reference information are immediately available to physicians with simple lightpen selections.

PHYSICIAN BENEFITS

New physicians coming on the staff at El Camino Hospital are given one hour of training in the use of the system and offered a second hour. After 2 to 3 months a physician usually feels comfortable using his areas of the system.

Physician usage of MIS is widespread and almost universal. Of the total possible orders, 75% are entered into the computer by the physician. These figures exclude phone orders, which have remained unchanged, and vary from 90% for OB/Gyn, 80% for other surgical areas, to 30% for the medical services. Actual computer usage by physicians is even higher. Of all physicians (except psychiatrists and pediatricians), there is an 88% chance that a physician will communicate directly with the computer during each day he has a patient in the hospital. These figures demonstrate the widespread use of the system by physicians.

General use of the system is divided into two areas: (1) obtaining information, and (2) recording information. This is true for all users; physician usage, specifically, will be discussed in detail by those categories. It should be noted here that no physician is forced to use the system directly.

RETRIEVAL OF DATA

This section refers to patient-oriented data contained in the system. The printouts will be discussed later.

Laboratory Data

All laboratory data are entered into the system by the laboratory, using a combination of direct interface for SMA-18 and Coulter-S; Mark-Sense cards for urine, bacteriology, and serology; and keyboard entry for all others. Anatomical pathology is not included.

All laboratory data can be viewed on the screen by any authorized user. These may be presented by department category but normally are presented as mixed data to physicians. Through the available pages he can identify the various tests by their ordering name (e.g., CBC, UAL, SMA-18, etc.). The physician always sees the latest reported test first and passes back through time as he goes to the next page. These pages, as mentioned, are filed by reporting times, not specimen times; therefore, when a physician pages to a test result he has seen before, this tells him there are no new tests and that he has seen all the available data. This organization of data is used throughout the system and is an extremely important concept. It is a method by which the physician guarantees for himself that he has not missed any data. This concept is called "reverse chronological data presentation by reporting time." It should be noted that specimen collection dates and times are shown on the displays, but the result reporting times are not shown to the physician.

Radiology Results

Radiology results are available to the physician at the terminal as soon as they are entered by the x-ray department and, again, are presented in reverse chronological order by reporting times. These results are entered by clerk typists in the radiology department using either "canned" statements within the computer system or typing the entire report, depending upon the desire of the radiologist. These results may be viewed with the words "Preliminary Report" attached until the radiologist verifies (signs) the report, at which time the preliminary report label disappears and a paper copy of the report prints at the nursing station. The HEW study showed that radiology results were available (on the terminal in preliminary form) on the average of 11 hours earlier than in the manual system.

Screen retrieval of laboratory and x-ray data is unquestionably the most important feature of the system to physicians. Not only are the data available anywhere within the hospital, but all distribution delay is removed and the system guarantees that the physician will miss no new results. It is a sobering thought that in the very early days, because of a number of problems, we physicians at El Camino seriously considered terminating entry of laboratory results. It is my opinion now that this would have eventually resulted in nonuse of the system by physicians.

Medical Order Retrieval

This feature is a system benefit which physicians must learn to use. While the system can present orders by entry sequence or in any other fashion desired, the category "Current Orders" is the one important to physicians. This is, of course, equivalent to the nurses "Kardex" in a manual system and is the running inventory of physician orders.

It is the usual habit of physicians to look only at the order sheet on patients' charts, which gives him a sequential list of orders written but does not allow him to review the current status of orders. Orders such as drugs and daily laboratory work can easily be forgotten and, conversely, by a slip of an eraser, an order may disappear forever from the nurses' Kardex.

Current order retrieval on the terminal shows the exact current status of orders. These orders are arranged by categories (e.g., all medications appear together) making it easy to evaluate the orders. Drugs that need to be reviewed are indicated on the display and pending laboratory work is marked "in process" if the specimen has been collected (the order disappears from "current orders" when the result is entered).

Nurses' Notes

All nurses' notes are entered into the system (Figure 1). There are many categories of nurses' notes and each may be retrieved by type or all may be retrieved together. They are always presented in reverse chronological fashion by reporting times.

Patient Status Information

All demographic and patient status information may be obtained in the terminal. All admission data are available, including diagnosis data, patient's physicians (attending and consulting), and bed assignment.

THE PAPER CHART

It should be made clear at this point that the El Camino MIS system does not include any normally handwritten or dictated physician's documents except medical orders. The system has these capabilities, but they are not considered cost effective. Undoubtedly, the paper chart will eventually disappear. We are not at that stage yet.

One of the major system revisions for physicians was improving the readability of

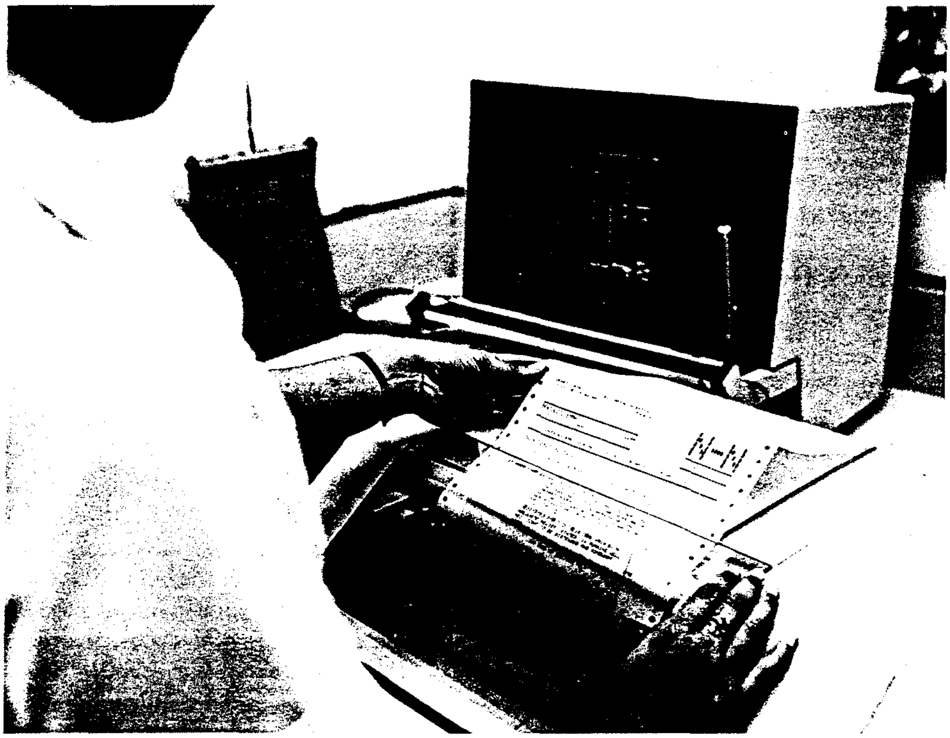

Figure 1. All nurses' notes are entered into the system through simple lightpen selections of words from preselected lists, and are presented in reverse chronological order by reporting times. The printouts then become part of the patient chart, which is stored on the nursing unit.

printed documents. This was done using graphic arts techniques to headline vital data.*

Early in the use of the computer system it became apparent that compromises would be required in the paper system. One physician's demand that the latest data always be available in the printed chart was not compatible with the physician who envisioned himself drowning in computer paper. An all-electronic "chart" on the visual display terminals was the solution to this conflict: all data are available up-to-date from displays *without* a flood of paperwork. Review of the history of print volume per day shows that El Camino is gradually decreasing the printed documents used and we expect to continue this. In spite of the decrease, we still print one-half million lines of print per day on 30 printers scattered throughout the hospital.

One paper document which deserves description is the "Cumulative Lab Summary." This document has now been in use for almost three years. The report is totally under computer table control and is variable by user hospital. The author felt it was imperative that the report be designed with time on the x-axis; however, a more important consideration was that the cumulative report be the only report in the chart.

*Sample documents are available from Technicon Medical Information Systems Corp., 590 East Middlefield Road, Mountain View, California 94043.

It rapidly became apparent that time on the y-axis is the only truly viable form of this report. The advantage of the x-axis time report is that all results for a single day (or reporting time) can easily be visualized. As an answer to this problem, we mark all results less than 24 hours old with an asterisk.

The cumulative laboratory summary always shows at least 7 days of data with all data being available in the chart. At the time of discharge, all laboratory printouts are discarded and a new cumulative summary for the entire admission is printed, which becomes a permanent chart document with all like data arranged side by side.

One of the early physician complaints was that color coding of laboratory slips was missing (red for blood, yellow for urine, etc.). With the advent of the cumulative summary, this coding was replaced by a position code as each test always falls in the same sequence. The values are arranged in medically significant categories and not by instrument names (we do not report an "SMA-18" on paper). We break down the sections so that electrolytes are together, etc. Values for a test always fall in the same column no matter what method is used nor how the test is ordered as long as the normal values are the same. If tests are done by different methods and with different normals, these results are reported in separate columns arranged side by side. Placement and contents of all columns and values are under table control and changeable at will. Furthermore, if desired, certain values may be presented in a noncomparative fashion.

The concept of a cumulative laboratory system has come under attack by certain laboratory computer system users. Their problems generally are due to the requirement to distribute these reports from the laboratory and inadequate initial design, specifically attempts to make the X = time report operate satisfactorily. At El Camino Hospital a new 7-day summary is printed each day a patient has new laboratory work. Stats and rushes are reported automatically at the time of result entry and not in summary format. All printing is done at the nurses' station. A physician may request a cumulative laboratory summary from the computer at any time without waiting for the automatic printouts. The cumulative summary makes it possible to have only one laboratory report in the chart at a time as the clerks throw away old summaries each time a new one is received. Finally, from a medical standpoint, a cumulative laboratory summary is an extremely important aid in the management of a critically ill patient and of no use on a routine admission. In order to use standard methods, however, we use the cumulative format on all patients.

As a final comment on the area of data retrieval, all computer tapes from the past are available. It is possible to reconstruct any past patient file from these tapes. Furthermore, it is possible to search these tapes for data across patient records (e.g., list all patients over 40 with an abnormal creatinine for the last four years if they have received gentamicin).

PHYSICIAN DATA ENTRY

All individuals perform data entry duties which result in secondary gain to themselves. For physicians, secondary gain is hard to define. It is the explanation of the differences between order entry statistics and computer usage statistics. To paraphrase, the physician uses the system in a way that he feels benefits him. Advantages of direct order entry to the physician are: the data are handled error-free; he can enter it from any terminal location; and he can take advantage of direct and indirect information built into the ordering displays. Furthermore, he may use department or personalized order sets in the process of order entry.

The mechanism of order entry is one of building a message for the computer by lightpen selection of user-oriented phrases. Unapparent to the user, the phrases carry along with them the necessary computer coding information to allow proper handling of the order (algorithms for addressing, scheduling, handling type-ins, etc. are all in use and are beyond the scope of this paper). In the event an adequate predetermined phrase cannot be selected, any message may be amended by typing a free text comment.

In general, the physician selects from the display the department, e.g., "lab," which takes him to the common laboratory tests display from which he usually makes his selection. If he selects a specific schedule, e.g., "Daily × 5", it will be followed; if he does not, a routine schedule for that specific test (under table control) is automatically followed (this refers only to the laboratory system). The reader at this point should be made aware that requisitioning into and reporting out of a hospital laboratory is an extremely complex area, and this paper is not intended to cover this subject comprehensively.

Another ordering area is drug orders (Figure 2). In this case, the computer recognizes the physician by his specialty and gives him a specific specialty ordering display. A drug name is selected and a predetermined medical order may be selected, or he may build any order he likes. Drug scheduling is totally "freewheeling" and there are literally no constraints. Built-in suggestions are present, however, that normally signal the physician to the correct drug usage. The computer edit programs will accept neither conflicting schedules nor schedules that cannot be interpreted. There is an "error override" mechanism that the physician may activate at this point which converts the order into a free text nursing order requiring the nurse to reenter and/or interpret the order correctly. This feature is of immense psychological advantage to the physician as it means that he can have the last word instead of the machine.

In the course of ordering, there are many pages of aids available to physicians. These include antibiotic characteristics, recommends for respiratory therapy, standards for isolation by disease, drug information, and availability information. In addition, standard orders are available in many departments. For example, all the routine coronary care orders are available through a simple lightpen selection.

Also available to all physicians are personal order sets which he may use and change at will. These sets are widely used. Well over 650 personal order sets are now contained in the system. These sets are used for all types of medical orders by general category (e.g., postoperative orders, admission orders) or by specific categories (e.g., pre-liver biopsy, postpartum).

Prior to hospital admission, the physician may write all his orders into the system to be activated when the patient arrives. This saves both physician and nursing time and ensures completeness of orders.

At the time of discharge, a display sequence has been designed which allows the physician to prepare a discharged summary on many patients without dictation; approximately 30% of the discharges are now handled in this way.

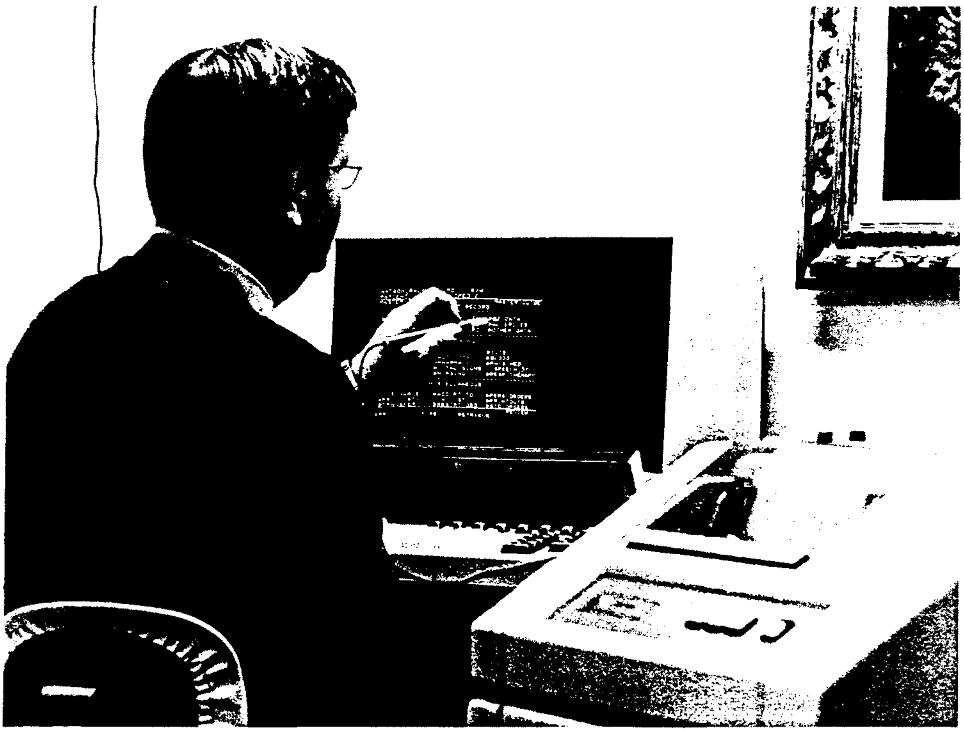

Figure 2. Physician usage of the computerized information system at El Camino Hospital is widespread. Here Dr. Watson enters an order for one of his patients, which will be immediately processed by the system, i.e., requisitions will print out automatically at the nursing station and in the pharmacy. This ensures legibility, less frequent medication errors, and instant communication.

Because a physician's computer (identification) code is accepted by the system as his signature, data entered by the physician do not require his personal signature. A number of security features are built into the system to prevent errors, particularly those which might be committed by the user.

A major area of development for physician usage has been providing medical information. While a number of categories have been tapped, the largest is a copyrighted surgical abstract system. A total of some 2,500 display pages are devoted to this type of medical information. The acceptance of this system is good and is viewed approximately 100 times per month.

NURSING ASPECTS

The bulk of professional use of the system is, of course, the nursing service. Not only do nurses have access to all physician functions (to act as their agents), but many other categories as well. These include all scheduling and preparation functions, nurse charting, central supply ordering, and, most important, a whole new concept of nursing care (see Figure 3).

Figure 3. Nurses have immediate access to all medical data for each patient under their care. The system holds and organizes the patient record and relieves the nurse from most routine paperwork, thus allowing the nurse more time to devote to direct patient care.

This concept revolves around the building of nurse care plans from expected outcomes contained within the computer system.[6] The care plan helps the nurse to be aware of the expected status of her patients for each day of hospitalization and makes it easier to detect deviations from normal. These same data are then used to carry out nursing audits for quality assurance. The data in the nursing care plan, along with an appropriate list of physicians' orders, are printed at the beginning of each shift for each patient and is the working document for the oncoming shift. While this is an expensive document in terms of computer time, its use is unquestioned.

Secondary gains for the nurse from this system are overwhelming and easily explain the complete nursing acceptance. New nurses coming on the staff are given a total of 8 hours training on the system using didactic and "hands-on" methods. It is considered that this time is roughly equivalent to that required to teach the previous manual system.

OTHER PROFESSIONAL ENTRIES

Many other user classes exist in the computer system. They encompass essentially all classes of hospital employees. A few of the important ones will be discussed, but this list is not comprehensive.

Pharmacy

Upon entry, all new drug orders print immediately in the pharmacy. All essential data are printed on the dispensing label, including known drug allergies. This is an elegantly simple method of approaching a problem that is difficult to solve within the computer itself. Now the pharmacist has both the drug order and allergies on the same label, thus making detection simple. In addition, the pharmacist may view the patient's complete drug profile on the pharmacy video terminal and may also peruse laboratory data.

On a daily basis for each floor, a medication supply list (by patient) prints out in the pharmacy. This gives the pharmacist the opportunity to review the drug profile on each patient daily. This medication supply list is the basis for the operation of the unit-dose pharmacy system that was installed with no increase in manpower at the time of computer installation.

Admissions

All admission and bedding functions are automatically handled by the system. Transfers are automatically made by a single lightpen selection which results in the reassignment of all patient documents to the new location. Orders are not rewritten or recopied when a patient is transferred. Demographic data are changed at will to correct spellings, etc., without risk of data confusion. Full preadmission and outpatient registration, reporting, and billing capabilities are present.

Business Office

The system contains a complete batch-operated off-line business office system. Information is passed from the on-line system to the off-line business system every 24 hours at midnight (both the Medical Information System and the Business Office System reside in the same computer). Approximately 80% of charges are collected automatically by the on-line system. The rest are entered by the business office through a video terminal (no keypunching is done) and represent such things as operating room charges.

Techniques of charge entry for other areas is variable depending upon the service. In general, charge entry may be done either at the time of requisition or use for any item, all under table control. The business office system itself contains all functions required for hospital operation and includes at least the following: accounts receivable, accounts payable, general ledger, payroll, job skills analysis, work-load analysis, and income analysis. These reports, produced by the off-line business office system, are printed off-site on a high-speed printer and delivered to El Camino Hospital. No other report deliveries are made.

ECONOMICS

The guiding factor in the economic area is a directive from the Hospital's Board of Directors: the system must not increase the cost of hospital care.[7] Through El Camino's Systems Engineering Department, full studies of this area were undertaken.

The 1974 conclusion remains in effect today: the system easily pays its own way, and this conclusion did not assign values for new capabilities allowed by the system. This information has been published[1] and is being reevaluated by Battelle Columbus Laboratories.

TECHNICAL DATA

The Technicon Medical Information System (MIS) operates on large-scale IBM computers (370 series). The data center servicing El Camino Hospital (located at Technicon's Mountain View offices), has a 370/155 computer with 1 megabyte of core and a backup 370/145 with 512 K of core. This center services both El Camino Hospital and Ralph K. Davies Medical Center in San Francisco (391 beds) on the same computer. El Camino is connected with two 50-kilobit analog phone lines (one could support the hospital, but with some response degradation) and Ralph K. Davies is served by one similar line with a dial-up spare.

Patient data base for El Camino consists of four 29-megabyte discs (118 megabytes). All displays and work in process are contained in another 29-megabyte disc, on which approximately 7,000 fixed displays are present. In addition, all system programs are contained on and called from another 29-megabyte disc which serves both hospitals. The display disc and data discs are individual for each hospital. The data discs also contain all tables for operation of the hospital.

There is a total of 150 input/output devices connected to the system. Video terminals are matrixed directly to the main frame; however, the printers are buffered by a minicomputer at each hospital. In addition, a minicomputer is used as a data acquisition device in the laboratory interfacing to the automatic laboratory devices.

The software is divided into two major areas: the first handling all terminal functions as first system priority, and the second handling retrievals, updates, report generation, etc. A major feature of the software is an exclusive data protection design. Minor software failures are detected and corrected automatically (a detailed description of this system is contained in the Battelle reports). It should be stated, however, that in five years of operation El Camino has never lost its data base. The system software has all been designed in a general table-driven fashion. This concept extends to the heart of the hospital organization allowing complete definitions of user classes, levels of authorized access, printer direction, etc.

SYSTEM PERFORMANCE AND RELIABILITY

It has been apparent for some time that system response times must be exceedingly fast in order for the professional user to accept the system. The true definition of the requirement is that the system must respond faster than the user can think. The level above which performance is considered unacceptable is 1 second for lightpen responses and changing fixed displays. The upper limit of acceptability is 3 seconds for other functions requiring look-ups, edits, etc. Nominal operation at El Camino is maintained at 0.4 second for lightpen selections and display changes (from request to completion of scan) and approximately 2 seconds for all other functions. These standards are difficult to obtain but absolutely essential.

System reliability is another extremely important aspect of system operation. Normal changeover to a backup computer takes about 5 minutes and occurs less than 10 times a month, normally for short periods of time as the smaller backup machine does not adequately carry the load. Longer "downs" are quite rare but do occur; the longest ever has been 6 hours. In five years of operation there have been less than five "downs" of similar magnitude.

Once every 24 hours, at 3 a.m., the system is down for 30–45 minutes for file duplication and program changes. Excluding this time, El Camino's MIS normal available time is 99.3–99.6% of total time. Below 99.4%, users perceive that the system is "not working properly." Experience has shown that this level of down time does not affect hospital function in any detectable fashion. An occasional user is affected when the system goes down while he is using the terminal. System downs for 20–30 minutes do not require procedural changes; longer "downs" require backup procedures. But by no means do they bring the hospital to a halt. This is partially due to the extensive nurse care plans on paper provided for the nursing service.

THE FUTURE

The future of the system is one of gradually encompassing hospital areas not now supported or inadequately supported. Many areas of direct assistance to physicians are possible but not touched at this time. System improvements will follow both the electronic industry and availability of funds.

CONCLUSIONS

The installation of a large-scale professionally oriented computer system at El Camino Hospital has been a success in all areas of involvement.* It is essential that any hospital considering such a system have a strong industrial engineering department. Benefits from the systems do not fall out automatically — they must be carefully and purposely collected.

There must be a key hospital employee, preferably a nurse, to act as system coordinator between hospital and vendor.

A physician to head the medical staff involvement is indispensable. His involvement must be complete and he must be able to communicate with and demand the respect of the rest of the medical staff.

Finally, for most hospitals, in-house development of a medical information system is totally inappropriate, not only from the standpoint of developing operational algorithms, but system architecture is extremely demanding and unforgiving. In this author's opinion it is inappropriate use of patient funds.

*This project survived because of the contributions of many individuals. These include all members of the medical, nursing, and systems engineering departments.

El Camino's installation is one of the early successes among a host of failures. But these systems will survive, and they will change the practice of medicine around the world.

REFERENCES

1. Norwood, D. D., Hawkins, R. E., Gall, J. E., Watson, R. J., and Cook, M., Information system benefits hospital, improves patient care. *Hospitals* 50:79–83, 1976.
2. Barrett, J. P., Barnum, R. A., Gordon, B. B., and Pesut, R. N. *Evaluation of the Implementation of a Medical Information System in a General Community Hospital.* Final Report, December 19, 1975, Battelle Columbus Laboratories, Contract HSM 110-73-331, Department of Health, Education and Welfare, Health Resources Administration, National Center for Health Services Research. NTIS Publication No. 248340.
3. Gall, J. E., Norwood, D. D., Cook, M., Fleming, J., Rydell, R., and Watson, R. J. *Demonstration and Evaluation of a Total Hospital Information System.* Final Project Report, December 1975. Contract No. HSM 110-71-128, Department of Health, Education and Welfare, Health Resources Administration, National Center for Health Services Research. NTIS Publication No. 262106.
4. Feldstein, Martin S., *The Rising Cost of Hospital Care,* National Center for Health Services Research and Development Information Resources Press, Washington, D.C., 1971.
5. Watson, R. J., Medical staff response to a computerized medical information system with direct physician interface. *Proceedings of Medinfo '74, Stockholm,* August 1974.
6. Cook, M., and McDowell, W., Changing to an automated information system. *Am J. Nurs.* 75:46–51, 1975.
7. Hawkins, R. E., Introduction of a user-oriented THIS into a community hospital setting — Introductory agents and their roles. *Proceedings of Medinfo '74, Stockholm,* August 1974.

EDITORIAL COMMENT

This paper represents a good presentation of the state of maturation of what must be regarded as the true prototype health information system. While there have been other similar systems in various stages of implementation in the past decade, none have dealt as directly with the most important issue of orienting the system to the medical professional who must use it on a day-to-day basis, and still try to do it in a cost-beneficial way, thus assuring its continued function even after "outside" funding sources have disappeared. For the medical professional to use it, the information must be reliable and accurate. For it to be reliable and accurate, it must be captured as close to its sources as possible, which necessarily means directly interfacing with a representative number of health providers who use it, including the physician.

In the past most other systems have skirted this issue in lieu of concentrating on functions which are easier to bring up and more impressive to the hospital administrator. Most computer applications in hospitals have concentrated their efforts on one small subsystem, usually the business office. Even when this subsystem handles patient care data such as those found in the clinical laboratory or pharmacy, it generally operates in relative isolation from the rest of the hospital, and therefore has little overall impact on the actual patient care process, short of some efficiency gained in its own sphere of operation. The notion that some espouse today of linking several of these isolated subsystems together without ever considering the impact of the process from the point of view of an overall plan of improved patient care seems only to promise to prolong the inefficiencies of such an approach.

To be sure, there are other systems which have used an overall patient-oriented approach. As Dr. Watson seems to be telling us in this article, most have failed because of their attempt to be "Total Information Systems." It seems appropriate to concentrate on the more cost-beneficial applications first — a total plan does *not* preempt some modularity in implementation, which is to be encouraged for many obvious reasons beyond the cost question. On the other hand, too many have avoided the difficult but necessary task of beginning at the base of the patient care process — namely, the physician's order. Again, it should be emphasized that someone's interpretation of a scrawled statement is *not* beginning with the physician's order. It is not accurate and reliable until he has actually verified his meaning directly into the system.

This MIS package is not a trivial consideration in terms of hardware and software. There have been many in the past who have questioned the need for rapid-frame generation for selectable lists because it takes 3–4 seconds to read a page. However, this response time is important because one who uses these lists daily becomes so familiar with them, they are soon committed to memory, and it is annoying to wait for the next selection list when you know where you are going. "Quick lists" only partially solve the problem, and thus *0.4 seconds* response time to refresh these screens is the figure expressed. I would suspect that the everyday user would find 1 second too slow, except for changing responses requiring look-ups, etc. This system then seems to establish good reason for the two 50-kilobit lines connecting the terminals to the computer site. It is not unusual to hear vendors scoff at this requirement in disbelief that doctors will even use the system (as they now *do* at El Camino), when what really concerns them is the software and hardware communication requirement with which they are not familiar. Data capture continues to be the function which paces the development of these systems.

Something more needs to be said about the concept of the Total Hospital Information System. Many vendors, including Dr. Watson's, continue to use this phrase very loosely. It is important to realize that Dr. Watson does not use this phrase once in his paper. In fact, he implies that there are many other applications still to be implemented, which in the El Camino setting seemed to be less cost effective. Whether the El Camino project has selected the right components or not seems to be a judgment which the reader must make for himself with some realization of what the history of this vendor's system has been.

In my experience of visiting numerous so-called "Medical Information Systems" (total and otherwise) over a number of years, it seemed useful to approach this problem by developing an idealized matrix of possible applications which might be used to assist the physician or other health care provider in taking care of the patient. The field is currently a taxonomic nightmare. Terms such as *medical record* or *laboratory system* or *computer diagnosis* are used as freely as the author wishes to apply them. This fact, combined with the extremely liberal use of the "future present tense," a phenomenon first pointed out by G. Octo Barnett, causes one to be faced with the reality that most of the written information on the subject is practically useless. A serious student of the subject is left only with the admonition to visit the installation directly. Even then one is confronted with similar applications being given different names, and different applications called the same thing from site to site.

Because of this situation, it seems worthwhile as an initial task of this journal to propose a practical classification scheme so that when various articles appear on the subject, one might have a basis for reference to clarify just what is being said, and sometimes even more importantly, what is being left out. As a start, a catalog of possible (and in most cases current and real) applications has been reduced into 12 functional groupings for ease in reference. As the field expands, these potential subsystems can become more refined and specific in their description. A logical grouping of components with related characteristics suggests the following.

THE HEALTH INFORMATION MANAGEMENT SYSTEM

1. Communications and Scheduling

Optimal patient care involves an enormous amount of information exchange for the purpose of bringing together various resources (people, information, and material). Such a communication system is the backbone of any health information management system; it is the element which links all the other subsystems together. The logistics of in-patient and out-patient scheduling is also a part of this function, involving the allocation of ancillary services as well as admissions, discharges, and census. The first step in the allocation of any of the hospital's, or any part of the health system's, resources is the generation of the physician's order. The order entry and result-reporting components represent the most basic information elements in the care of the patient.

2. Administrative Management

Good administration of medical facilities and services demands both retrospective and prospective analysis of vital management information, such as patient accounting, cost accounting, medical staffing, facility usage, budgeting, inventory control, and preventive maintenance. It includes the capability of creating simulation models of the operating health care system for analysis, planning, and redesign. It covers all levels of administrative information, from individual patient encounters to that necessary to manage the largest government facility.

3. Patient Data Base Acquisition

This includes various techniques for the acquisition and processing of all elements of the patient's history, physical examination, and progress notes. It also embraces all other methods used to develop the basic patient data base, including consultant reports, multiphasic health testing, nurses observations, and other elements contributed by various support personnel operating essentially as physician extenders.

4. Nursing Services

This subsystem includes all processes which directly support the nursing care team in administering patient care. For example, it incorporates the scheduling and prompting of direct nursing care functions, including shift change summary reports on each patient's care and condition. It also includes the regeneration of all doctor's orders on demand, and any nursing station administrative functions not covered specifically in another subsystem.

5. Patient Support

All components which involve patient comfort or therapeutic adjuncts to nursing care are combined in this subsystem. This includes inhalation therapy, occupational therapy, and physical therapy, as well as central supply. It also includes the food service components, incorporating areas such as menu planning, nutritional accounting, and the food control elements of procurement, inventory, preparation, and cost accounting.

6. Diagnostic Support

This subsystem brings together all the components directly supporting the diagnostic workup. Though a somewhat heterogeneous grouping, most elements include the acquisition of an analog signal, analog-to-digital conversion, and an automatic or semiautomatic interpretation. This refers to such areas as electrocardiography, electroencephalography, pulmonary function, and newly emerging elements such as electronystagmography or electromyography, or computerized axial tomography. Support for nuclear medicine is also included with this group, as is computer-assisted diagnostic consultation.

7. Laboratory

All elements of the clinical laboratory fall into this subsystem involving areas such as chemistry, hematology, microbiology, immunology, microscopy, virology, and blood banking. In addition, it encompasses other elements of pathology, including histopathology (cytology), surgical pathology, and gross specimen analysis, involving areas such as autopsy reporting and forensic pathology. It includes aspects of quality control, trend analysis, laboratory instrument monitoring, result reporting and interpretation, and positive control of each specimen or body fluid.

8. Pharmacy

The information aspects of therapeutic agents and their usage are all grouped under this subsystem. These include drug inventory control, prescription formulation, maintenance of a formulary, and appropriate aspects of clinical pharmacology such as usual dosage, order checks and reminders, and contraindications and hypersensitivity reactions. Appropriate aspects of clinical toxicology and acid–base (fluid) therapy are also components of this subsystem.

9. Radiology

Components involving diagnostic radiology include facility and technician scheduling, patient preparation notices and reminders, techniques for reporting and interpreting individual roentgenograms, and film file inventory control. Therapeutic radiology includes support for treatment calculations (including isodose curve plotting), generation and maintenance of patient treatment schedules, as well as tabulation of results (Tumor Registries).

10. Patient Monitoring

These components all involve the integration and presentation of large (continuous) amounts of physiometric data by sophisticated instrumentation in environments such as the Intensive Care Units (general, cardiac, burn), Recovery Rooms, Delivery Rooms, or Emergency Rooms. It also includes continuous monitoring functions which may not be on-line, such as dynamic cardiography.

11. Library

The Health Information Management System requires a capability to maintain and update a large number of relevant computer displays, including those for input of various elements of data, those which incorporate "capsules" of important medical reference information, and those which parallel the physician's diagnostic logic process. Such an enormous requirement demands a separate subsystem, which is closely aligned with the more commonly recognized reference information generation function of the Medical Library, and suggests a new and appropriate role for this valuable resource.

12. Health Records

The capturing of data by each of the other subsystems generates a data base which gradually incorporates the entire patient medical record as we know it today. This subsystem refers to the advanced information management components which are associated with this information, such as areas as prospective and retrospective statistical analyses and the generation of various types of output reports. This last function includes the development of statistical compilers and other techniques for the on-going correlation and auditing of health information parameters such as diagnoses, therapy, and the tracking of the clinical progress of disease (epidemiology). It also includes components involved with the nomenclature and coding of disease processes, as well as techniques to monitor the quality of care being administered.

As one reviews the applications described in the previous article, which represent probably the closest assimilation of applications approximating a Health Information System which is currently available, one recognizes many components of the matrix which are not present. Dr. Watson has represented those present as examples of applications with the greatest potential for cost reduction in the environment of El Camino Hospital, a reasonably typical community hospital. These represent portions, though not all, of the functional areas of *Communications and Scheduling* (order entry, results reporting, Admission–Census–Discharge–Transfer); *Administrative Management* (the Business Office System and charge capturing); *Nursing Services* (nearly all of the functions described); *Patient Support* (Central Supply ordering); *Laboratory* (at least clinical laboratory functions); *Pharmacy* (labels, patient–drug profiles); *Radiology* (a selectable results-reporting scheme); *Library* (Surgical and other abstracts as well as numerous other reference frames embedded in the system); and *Health Records* (Discharge Summary support techniques).

The comment is made that the future involves "encompassing hospital areas not now supported or inadequately supported," including "many areas of direct assistance to physicians . . . not touched at this time." From our matrix we can see that this potentially represents functions in areas such as those described under *Patient Data*

Base Acquisition, Diagnostic Support, and *Patient Monitoring* in addition to filling out some of the functions in the other subsystem descriptions.

To be sure, the Total Health Information System is still a dream of the future, and perhaps that is as it should be, but one should not lose sight of the reality that El Camino (and other Technicon MIS sites such as Nebraska Methodist and the National Institutes of Health) are bringing up systems with a significant degree of integration which can only lead to better patient care in our fragmented health care system. We are indebted to Doctor Watson for presenting this picture of the state of the art.

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