Policy Implications of Medical Information Systems

December 1977

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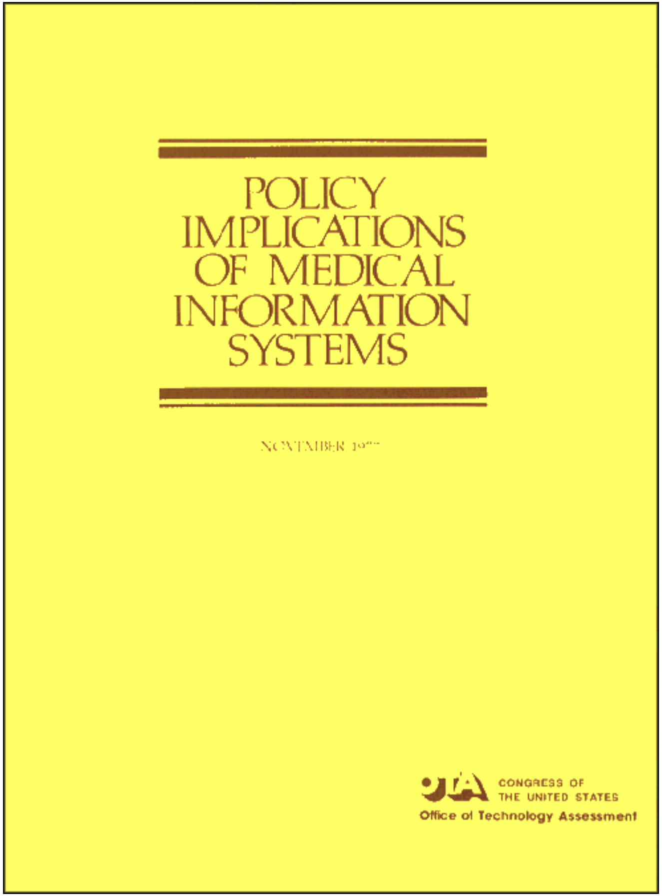

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Congress of the United States
OFFICE OF TECHNOLOGY ASSESSMENT
WASHINGTON, D.C. 20510

OCT 28 1977

Committee on Human Resources
u. s. Senate
Washington, D. C. 20510

Gentlemen:

On behalf of the Board of the Office of Technology Assessment, we are pleased to forward the results of the assessment requested by your Committee.

This report provides a balanced and impartial analysis of medical information systems. We hope that this analysis will serve as a useful resource for continuing evaluation of the issues it discusses.

Sincerely,

Edward M. Kennedy
Chairman

Sincerely,

Larry Winn, Jr.
Vice Chairman

Enclosure

FOREWORD

This report is an assessment of the policy implications of computer-based medical information systems. It was requested by the Senate Committee on Human Resources because of increased concern over the quality and rising costs of medical care.

The Committee asked the Office of Technology Assessment to examine:

1. The benefits and limitations of medical information systems;
2. The factors influencing their adoption; and
3. Policy alternatives for the Federal Government with regard to such systems.

The report begins with a summary of the findings and conclusions and the alternative policies that could be pursued. Chapter 2 provides a perspective for the assessment. Three different kinds of medical information systems that were examined are described in chapter 3. Chapter 4 discusses the implications of these systems on such areas of concern as quality of medical care, clinical decisionmaking, malpractice litigation, and confidentiality of data about patients. Chapters considers the factors that influence the diffusion and use of information systems in the medical field. In conclusion, chapter 6 considers a range of policy alternatives for maximizing the benefits of information systems.

This study was conducted by staff of the OTA Health Program with assistance from an advisory panel, chaired by Kerr L. White. It was reviewed by the OTA Health Advisory Committee, chaired by Frederick C. Robbins, and by a wide variety of individuals in the medical field, industry, universities, consumer organizations, and Government. The resulting report is a synthesis and does not necessarily represent the views of any of the individuals who participated in the assessment or the review process.

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SUMMARY

1. SUMMARY

The complexity of medical care has greatly increased during the past 30 years. More technology, more professionals, and more support services are involved in the care of patients than ever before. Today's medical care institutions encounter problems coordinating and communicating massive quantities of data necessary for clinical care. Medical professionals must note and remember increasing amounts of data about each patient from an expanded number of diagnostic tests and therapeutic procedures. Physicians are also faced with the task of memorizing information about new diagnostic tests and treatments, knowledge that must be constantly updated.

Outside the clinical context, other changes have increased data that must be retained about each patient. Third-party payment systems, particularity the Federal programs Medicare and Medicaid, have raised requirements for data to ensure validity of beneficiary claims. Other Federal and State programs for quality review, planning, regulation, and research have brought additional demands for recordkeeping. And the increase in malpractice litigation has created new pressures for careful documentation of clinical treatment. Traditional handwritten medical records have not kept pace with the rising demands placed on them.

The application of computer technology offers a possible solution to these problems. Called medical information systems, this new application promises to change the medical record from a historical document to timely, accurate information that is instantly available to all those involved with patients. Medical information systems can be used to educate and assist medical professionals during clinical care, reducing the need to rely on memory. Potentially, they can increase efficiency and reduce or contain institutional costs. They can provide a way to monitor and evaluate the quality of medical services. They can eliminate duplication of data collection and can provide accurate, accessible data for evaluating and planning medical care services. Finally, they can be used to supply data that have previously been unavailable to researchers and policy makers.

For purposes of this report, a medical information system is defined as a computer-based system that receives data normally recorded about patients, creates and maintains from these data a computerized medical record for every patient, and makes the data available for the following uses: patient care, administrative and business management, monitoring and evaluating medical care services, epidemiological and clinical research, and planning of medical care resources.

No existing medical information system yet provides data for all of these purposes. Those in use were developed through the independent efforts of many investigators and consequently display a diversity of technical approaches and philosophies. For the most part, they are prototypes and vary in goals, costs, and impact.

This variation, as well as the developmental status of the technology, makes assessment of benefits and limitations difficult. Few careful evaluative studies have been conducted to date. However, recent breakthroughs in computer technology can be expected to increase the availability and reduce the costs of medical information systems. Without a Federal policy toward these systems, their diffusion may well proceed indiscriminately and standardization will not be possible. If so, the full potential of medical information systems is not likely to be achieved.

FINDINGS AND CONCLUSIONS

Benefits and Limitations

Institutional Delivery of Patient Care. Evidence indicates that by facilitating communication and reducing errors, medical information systems improve the patient care delivered in medical care institutions. Some errors are reduced because the computer systems help ensure that data about a patient are accurate, available, legible, complete, timely, and organized. Through their mechanisms to check whether orders have been carried out, medical information systems also monitor performance and prevent some errors of omission.

Support of Clinical Decisionmaking and Physician Education. Some medical information systems support clinical decision making by supplying physicians with appropriate medical knowledge and patient data during clinical care, thus reducing their need to rely on memory. By incorporating valid findings of medical research into programs, systems can also facilitate the spread of new medical knowledge and provide continuing medical education. Preliminary studies indicate that errors of omission by physicians are reduced if timely reminders are provided by the computer systems. Further evaluations are needed, however, to confirm whether physicians' performance is changed.

Assessment of the Quality and Utilization of Medical Care Services. Medical information systems can be programed to assess the quality of medical services provided against agreed upon standards for acceptable care. Appropriateness of inpatient facility use can also be monitored. These legally mandated functions could be accomplished without the expense of any additional data collection. Medical information systems have been used for this purpose in only a few experimental programs, each of which has been limited to a small number of clinical conditions.

Malpractice Litigation. Whether medical information systems would increase or decrease malpractice litigation is debatable. Computerized medical records document the conduct of medical therapy. They could eliminate some causes for litigation by reducing errors in patient care. Errors that do occur could be highlighted, however, and lawsuits increased. No evidence is available to support either hypothesis from institutions using medical information systems.

Roles of Medical Care Professionals. Medical information systems reduce or eliminate paperwork at the same time that they make available information needed for optimal job performance. Thus, medical care professionals can make greater use of their knowledge and skills and assume increased responsibilities. However, there is insufficient evidence to conclude that personnel actually perform new duties or that their productivity increases in activities related to patient care.

Health Data Systems. Health data systems are collections of data organized for a variety of purposes including reimbursement of health services, utilization review, assuring quality of care, and planning, monitoring, or evaluating medical care services. Medical information systems could supply these health data systems with data more accurate and more accessible than those currently available. If standard classifications and codes were used and if all data sent to health data systems were already in computerized form, these organizations would be likely to realize substantial cost savings. At present, no medical information system is coordinated with health data systems. Further, health data systems aggregate data from more than one source and could thus take advantage of medical information systems only if widespread adoption occurs.

Planning and Research. Medical information systems could provide planners and medical researchers with data that are not readily available from existing health data systems. The computer systems store a data base that permits detailed analysis. Such analyses are now attained only with the difficulty and expense of special studies. With this kind of data, managers of institutions could predict needs for new supplies, personnel, and facilities. If medical information systems with compatible data bases and standard definitions were widely adopted, they could be used to plan medical services resources, to evaluate the cost and efficacy of medical care, and to conduct clinical and epidemiological research on patients' problems, conditions, and diseases.

Confidentiality of Patient Records. The confidentiality of sensitive medical data could be violated if computer files were infiltrated by unauthorized persons. In addition, computerized records facilitate the availability of detailed data to organizations outside of medical care institutions. At present, each facility using a medical information system has developed its own security precautions to maintain confidentiality. Today computer records are more secure than manual records. However, medical information systems are not in widespread use, and a potential problem does exist.

Factors Influencing Adoption

Acceptability to Medical Care Providers. Medical information systems require medical professionals to record information in a specified manner, and some professionals could resist changing established practices. Persuading physicians to adopt this innovation proved a major hindrance with early systems. More recent experience with the computer systems described in this report indicates that familiarity with a system encourages medical personnel to accept it. Providers who regularly use a system strongly support it, while those who are only occasional users sometimes find fault with it.

Technical Transferability. Prototype medical information systems have been proven technically feasible, but most have not yet been made adaptable to the various conditions of different institutions. In order to realize the benefits of a standardized data base and to market systems economically on a large scale, flexible systems are required. Efforts to make existing medical information systems transferable are now being initiated.

Cost. Medical information systems are an expensive technology. Operating costs for a hospital-based system range from $4 to $9 per patient per day. For systems based in ambulatory care sites, costs range from $0.50 to $14 per patient visit.

Costs of implementation are high. Costs are, however, likely to decrease in the future, because of lower prices for computer hardware and higher volume, Moreover, a majority of both hospitals and ambulatory care facilities now using medical information systems report overall savings in institutional costs due to their computer systems. At least one study has documented cost savings. In particular, savings are experienced in labor expenses.

General Factors. Rate of adoption of medical information systems will depend on multiple factors applicable to any new technology. New developments in computing hardware and software, Federal policies, and economic incentives and constraints could facilitate or impede adoption. The effect of these factors on medical information systems is not now predictable.

POLICY ALTERNATIVES

At present, the National Center for Health Services Research in the Department of Health, Education, and Welfare supports research on medical information systems through grants and contracts to independent investigators. The commercial computer industry, the major developer of medical information technology in the past, is conducting some new research and directing efforts toward limited marketing of prototype systems.

The Federal Government could continue current policies and allow adoption of medical information systems to be determined in the open marketplace. However, this policy could result in medical information systems being marketed and adopted without additional investment in research to improve certain capabilities. Because capabilities to improve and monitor the quality of medical care and to facilitate research and planning are the least developed and require standardization, these potential benefits for patients and the medical care system might be lost. Computer systems limited to administrative and financial functions could continue to dominate the market. Medical information systems that might be used could also lack high standards of quality or provide inadequate protection for the confidentiality of patient data.

If Federal action influencing development, standardization, and eventual use of medical information systems is considered appropriate, a range of policy alternatives could be pursued. These alternatives are illustrative and not mutually exclusive. Addressing problems through several mechanisms may be most effective.

- Establish a central clearinghouse to coordinate developmental projects and provide information to the public about medical information systems.
- Provide funding for evaluation of medical information systems in a number of different medical care facilities and locations to determine their effectiveness in terms of relative benefits and costs.
- Ensure the availability of medical information systems with specified capabilities and applications by contracting for their design and development.
- Provide incentives for medical care facilities to adopt medical information systems that improve the quality of patient care and support research and planning.

- Authorize a central organization to develop, validate, and maintain the content of medical knowledge within medical information systems.
- Develop standardized medical data bases, including nomenclature, terms, definitions, classifications, and codes for use in medical information systems.
- Establish guidelines for precise standards to protect confidentiality of patient data within an institution and release of identified data to third parties.

SCOPE OF THE STUDY

There are three boundaries on the kinds of computer systems considered in this report. The first boundary is that this study discusses only those computer systems that electronically store at least part of the individual patient's medical record. The capability to accumulate and retrieve data for each patient is critical for both the process of patient care and research.

A second boundary limits discussion to broad-based systems that could provide information needed by a medical care institution as a whole. Although computer applications such as automated clinical laboratories, pharmacy systems, intensive care monitoring systems, and financial systems can benefit particular areas of clinical care or institutional management, this study excludes computer systems applicable only to such specialized units or functions.

Third, this report assesses only computer systems that can provide information about patients during the clinical care process. This boundary limits consideration to systems meeting two technical requirements. First, the computer itself must be directly linked to both the stored data files and those medical care providers who enter and use the data; such a system is referred to as "on-line." Second, the computer system must process and return data quickly enough to be used; such systems are said to operate in "real -time." However, systems can combine "on-line" and "off-line" methods for entering and displaying data.

This report does not attempt to survey the field and categorize systems by design and capacity. Three advanced systems are described to illustrate potential implications of this new technology for patient care in particular and, more generally, for the whole medical care system. Although an important capability of medical information systems is to provide necessary data for administrative and business needs, implications of medical information systems for these areas are not examined in this study because computer applications performing similar functions are already widely in use.

ORGANIZATION OF THE REPORT

Chapter 2 defines the basic capabilities of medical information systems and gives a historical overview. Major problems that have hindered development are reviewed: variations in medical care, inadequate computer hardware and software, and inadequate commitment of capital for long-term development.

Chapter 3 describes the three medical information systems referred to throughout the report. One system, Technicon's Medical Information System (TMIS), is de-

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signed for acute care hospitals. Its use at El Camino Hospital in Mountain View, Calif., is reviewed. Another, the Computer Stored Ambulatory Record (COSTAR) system at the Harvard Community Health Plan in Boston, Mass., is designed for ambulatory care. The third, the Problem-Oriented Medical Information System (PROMIS), can be used in either setting, although the prototype operates in an inpatient facility at the University of Vermont Medical Center.

Chapter 4 discusses the implications of medical information systems for institutional delivery of patient care, clinical decision making and physician education, assessment of the quality and utilization of medical care, malpractice litigation, the roles of medical care professionals, health data collection systems, planning and research, and confidentiality of patient records.

Chapter 5 reviews factors that will influence the use of medical information systems: acceptability to medical care providers, technical transferability, cost, and general factors that influence the use of any new technology.

Chapter 6 summarizes alternative policies for the Federal Government in relation to medical information systems. Possible actions directing development, standardization, and dissemination of the technology to ensure maximum benefit for the medical care system are discussed.

2.

BACKGROUND

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BACKGROUND

Medical information systems are being developed on the premise that a medical care institution gains the greatest efficiency, economy, and benefit if a single computer system meets all its needs for information (37). Although almost 90 percent of all hospitals in the United States already use electronic data processing in some form, for the most part, only business and administrative functions are automated **(52).** Few medical care facilities use a computer to support activities related to clinical care.

Medical information systems combine both administrative and medical data into a common set of data files (or data base) for processing by the computer. Once computerized, the data are available for all authorized purposes within the institution. This chapter describes the basic capabilities of medical information systems and reviews the history of their development and funding support.

CAPABILITIES

Ideally, medical information systems perform four functions (10):

- Capture data normally recorded about each patient and store the data in a computer record.
- Provide any appropriate part or all of these data, on demand, to medical care providers for patient care and to administrative and business offices.
- Provide administrative and communicative functions, such as sending messages among various departments, scheduling appointments and procedures, and posting charges and preparing bills for the business office.
- Provide a data base useful to investigators for quality of care assessment, clinical decisionmaking, epidemiological and health services research, and planning and evaluation of medical care.

Meeting all of these needs places extensive technical demands on a medical information system (8). Providers of patient care require data quickly. Medical information systems can meet this requirement only if patient data files are stored within the system and computer terminals give medical users immediate access to these files. In such a system, described technically as “on-line,” computer terminals are connected directly to the computer’s central processing unit, which calls in and processes data stored on computer tape or disks as required. In order for data to be easily available, multiple computer terminals need to be located in all areas where data about patients are entered and used (see figure 1). To provide information for physicians and administrators making decisions, the computer system must be able to quickly manipulate and analyze data in many ways helpful to them. Satisfying this requirement calls for careful structuring and definition of the data base as well as sophisticated software. Finally, researchers need a medical information system with capacity to store massive amounts of data on large populations for long periods of time.

Advances in computer technology have made all these capabilities technically possible, but no medical information system at present performs all four functions. Existing systems emphasize different capabilities and vary widely in scope of application. One system, for example, transfers patient data efficiently from one service unit to another, but has no capability for the long-term storage of patient records. Another system offers extensive aid to clinicians making decisions about medical treatments, but does not generate administrative reports or prepare patient bills.

Medical information systems have some common features. All use a computer for organizing entries of data, patient records, or reports; maintaining data files on patients; computing; abstracting and summarizing data; generating reports; and message-switching (2). All systems include some kind of bulk storage and various types of terminals for entering and retrieving data.

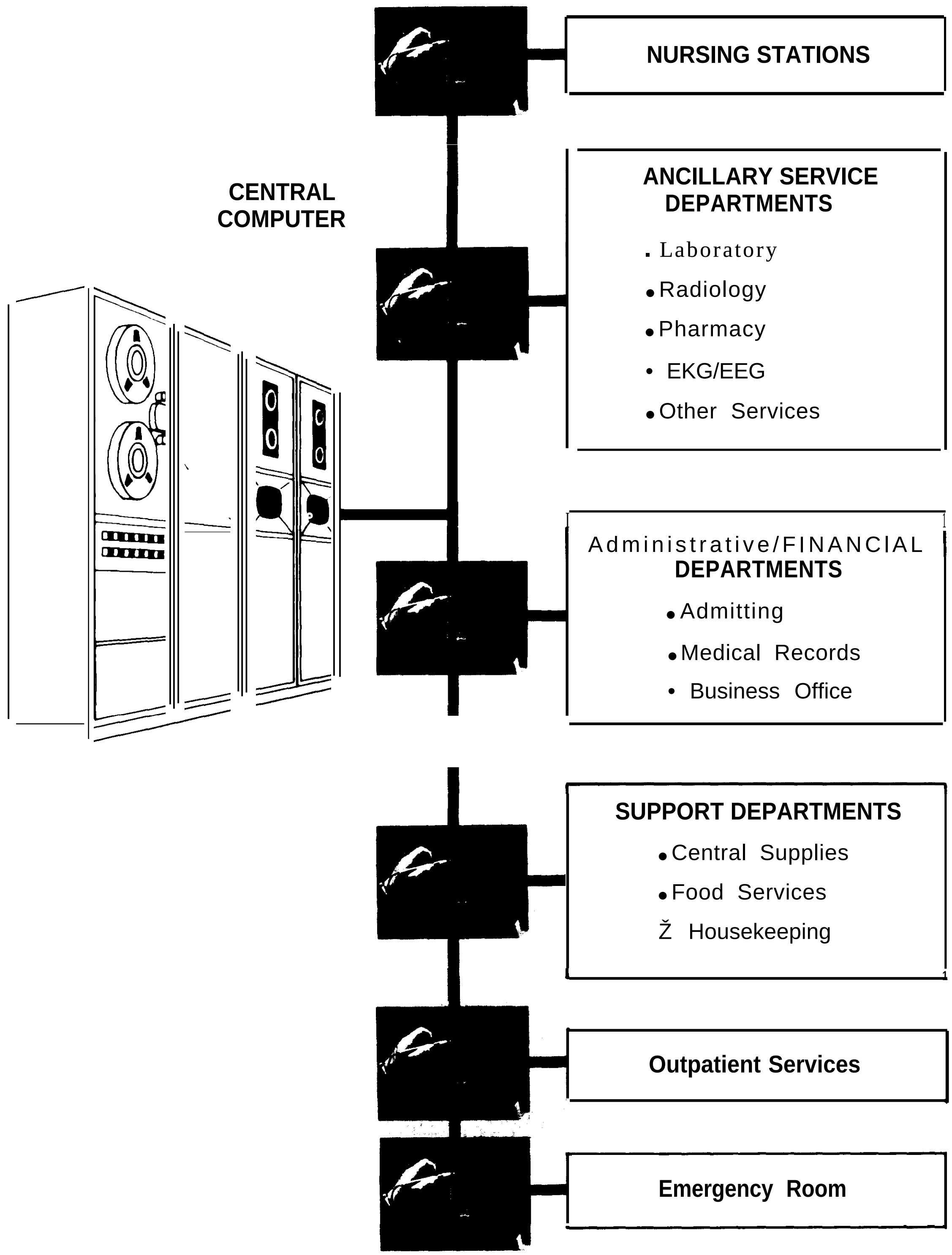
Medical information systems vary, however, in such technical aspects as use of large or minicomputers, location of the computer onsite or shared computer services off site, data entry and retrieval devices, storage of data in the system, and programing language. Other variables include who enters and retrieves data about patients, the extent to which the medical record is computerized, whether narrative information is allowed, which patient data are coded, and in what form data are retrieved.

Because systems differ so much, the term "medical information system" can be confusing. The label has been applied to computer systems ranging in function from single purpose subsystems for scheduling patients or for diagnosing single diseases to complex systems that attempt to provide comprehensive information for an institution. Because medical information systems have been developed through the independent efforts of many investigators, today's systems reflect a diversity of philosophies and technical approaches.

DEVELOPMENT AND SUPPORT

Both the computer industry and the Federal Government have recognized the potential of computers to process the medical data needed for patient care. Computer applications for the clinical management of patients, however, have not been developed as rapidly or accepted as widely as financial and administrative applications. In the mid-sixties, Federal requirements for accountability in billing spurred the development of a great number of computer applications for hospital business offices. Computers were also used for such tasks as collecting bills, managing hospital resources, and keeping track of patients within the hospital. These computer systems succeeded both because there was sufficient demand for them by medical care institutions and because the necessary technology had already been developed and used in other fields, such as banking and the airline industry.

Figure 1-HOSPITAL DEPARTMENTS WHERE COMPUTER TERMINALS ARE LOCATED



Developing computer systems that provided necessary data for patient care as well as supported management functions posed a different set of problems. A number of early attempts to install integrated information systems in hospitals were costly failures. These projects, which were launched in the mid-sixties, were typically initiated by private industry with the cooperation of pilot hospitals. At times, Government research funds gave some support. A review of these unsuccessful projects cited three primary reasons for their failure: inadequate understanding of the complexity and variations in medical care; inadequate computer hardware and software; and inadequate commitment of capital for long-term development (10).

Variable Medical Care. The fundamental requirement of a medical information system is that it store all pertinent data about each individual patient in an integrated computer record. The nature of medical care itself complicates computerizing the entire medical record. No rules specify what information should be entered into the medical record in clinical care. Style, format, and language typically differ from one institution to another and from one clinician to another (12). In addition, because the medical record contains narrative as well as numerical data, a potentially unlimited amount of information has to be structured and possibly codified for entry into the computer (22).

This problem has been somewhat resolved by having developers of medical information systems work closely with physicians and other medical care providers to define data bases in language and formats acceptable to individual institutions. In most systems, the complete medical record has not been computerized. Sections that are primarily numerical and defined, such as orders for and reports on laboratory tests, medications, and routine procedures have long been computerized. Narrative sections of the medical record that vary in content, such as physicians' notes on a patient's progress during therapy, have either been added incrementally to or excluded from the computer record.

The lack of a precise and complete vocabulary hampers communication between computer systems and providers. Substantial research is needed to analyze the content of medical data in terms, for example, of the frequency of various items. Such research would aid in the development of a terminology that is consistent with medical standards and that gives medical care providers flexibility in entering and retrieving data. At present, lack of standardized nomenclature or established protocols in medical care continues to constrain the development of a generalized data base (9).

Computer Hardware and Software. Developers of medical information systems have also had to resolve a number of technical problems in order to meet the requirements of the medical care environment. In order for data to enter and leave the information system quickly, medical care professionals need to communicate with the computer directly. Designing a system that permitted direct communication was a major obstacle. Developers eventually designed computer terminals that were easy for providers of patient care to use. Computer terminals consist of a cathode ray tube (a television-like screen) and a typewriter keyboard. In some systems, the medical professional enters or retrieves data by touching, by "pointing" a lightpen, or by pressing a button to the left of the desired item displayed on the video screens. Typing on a keyboard has become a supplementary, rather than a primary, means of entering data. High-level computer languages that resemble conversational English have also been developed to facilitate changes in programing.

Early systems were slow in responding to inquiries from medical care providers. Physicians and nurses found that using these systems to enter or obtain data was more time consuming than traditional methods. As hardware costs gradually decreased, computers that responded almost instantly became feasible. Medical information systems now usually respond in under 2 seconds.

If providers are to rely on medical information systems, the computers also have to operate 24 hours a day. Systems installed in the late sixties had frequent "downtimes," but considerable progress has been made. The prototype medical information systems currently in use operate over 99 percent of the time. Backup computers ensure necessary support for medical care providers.

Today, technical limitations are of a different nature (39). Recent advances in computer technology are providing smaller and much less expensive hardware, but are also raising new problems for software and for communication between provider and computer. The use of microprocessors, for example, requires the development of systems software that is more transferable. Software for application programs also continues to need further development. For example, techniques allowing software to be easily modified for different settings are available, but have not yet been generally applied in medical information systems. Also, low cost, portable terminals are not yet widely available. Because medical care professionals see patients in a number of locations, the absence of easily portable terminals has hindered clinical applications.

Funding Support. A third major problem area has been the lack of long-term commitment of capital. Development of medical information technology has been characterized by high costs and long lead times. A survey of ambulatory care sites with automated medical record systems reported developmental costs ranging from $100,000 to $10 million, with the majority of computer projects costing $100,000 to $300,000 for development (23). projects required 1 to 7 years of research and development before they became operational. No similar survey of hospital-based medical information systems is available. Two systems that are currently operational, Technicon's Medical Information System and National Data Corporation's VITAL, cost $25 million and $12 million respectively to develop (2). Development of the former by the Technicon Corporation and its predecessor, Lockheed, spanned 10 years.

Funding for development of medical information systems has been provided by private industry, the Federal Government, and, in some cases, medical care institutions themselves. Although commercial groups have emphasized applications for administration, billing, and accounting, private industry has nonetheless been the major source of funding for the research and development of medical information systems (13). Total expenditures are unknown, but far exceed those of the Federal Government.

The principal agency charged with developing medical information systems technology in the Federal Government is the National Center for Health Services Research (NCHSR) in the Health Resources Administration of the Department of Health, Education, and Welfare. Other Federal funds for special projects in this area have come from the Bureau of Health Manpower and the Indian Health Service in HEW, as well as the Veterans Administration and the Department of Defense. NCHSR makes grant funds available to investigators for research and/or demonstration projects in medical information technology. In the 7 years since its establishment in 1969, NCHSR has spent a total of $26.6 million for projects relating to medical information system s.*

According to some investigators, however, project funding is sporadic, subject to annual approval, and often limited compared to the scope of the project (10, 20). In addition, in recent years funding support by Government has been decreasing from the levels of spending in the late sixties and early seventies. Expenditures by NCHSR for grants relating to medical information systems decreased from a high of $4.6 million in FY 1974 to $3.3 million in FY 1976. * As a result, competition among investigators applying for grants has become much stiffer, and some projects have been discontinued.

Support by private industry for research on medical information technology has fluctuated. The computer industry developed the basic technologies for medical information systems in the late sixties and early seventies, but many companies have not marketed their developmental projects. A 1973 publication listed 15 computer companies actively developing integrated information systems for hospitals (4). Only five of these companies had operational systems installed in hospitals in 1976. These five medical information systems, marketed by the Technicon, National Data Communications, Data Care Systems, McDonnell Douglas, and Medicus Systems Corporations, are now operational or in the process of being installed in approximately 20 hospitals around the country (2, 15). Two equipment manufacturers, IBM and the Burroughs Corporation, offer a variety of applications that can be combined to develop an integrated system, and a few medical care institutions are developing their own inhouse modular systems from subsystem applications (2). A modular system could permit, for example, an institution to begin with administrative and business systems and later expand to include clinical applications. .

There are no other broad-based systems operational in hospitals. One hypothesis is that the long developmental time lag, frequently 5 to 10 years, and the prospect of a low volume market discouraged industry in the past (16). However, a number of companies, building on advances in computer technology, are now developing new systems using minicomputers (32).

A 1974 survey of ambulatory care identified 175 sites that operated computer systems with some medical data content (23). These systems were diverse in their application; most were developed for a specific purpose and collected only minimal clinical data. Although at least 14 commercial vendors were identified in the survey, none offered a system that computer processed all the data used in providing patient care. Only four sites had systems in which all reported data were computerized: the Harvard Community Health Plan in Boston, Mass., the Cardiovascular Clinic in Oklahoma City, Okla., Brunswick Naval Air Station in Maine (not now operational), and the Medical University of South Carolina at Charleston, S.C.

The source of funding for projects at the 18 sites visited during the survey was approximately evenly divided between internal funds and external sources, primarily Federal grants. Nearly every site was still developing some aspect of the project and thus continued to need internal support or direct Federal appropriations.

•Based on expenditures for FY 1971 through FY 1976 supplied by the Department of Health, Education, and Welfare.

Thus, although substantial advances, especially technical ones, have been made, conceptual and funding problems continue to constrain the development of medical information systems, Because current developmental projects are diverse in capacity and degree of comprehensiveness, they have different goals, impacts, and costs. No consensus has been reached on the defining characteristics of medical information systems.

3.

DESCRIPTIONS OF THREE SYSTEMS

3.

DESCRIPTIONS OF THREE SYSTEMS

Because of the different goals, impacts, and costs of existing medical information systems, no single system can be considered representative. In order to illustrate this diversity, three systems are described in detail. One system, the Technicon Medical Information System (TMIS) at El Camino Hospital, is specifically designed for the acute care hospital. Another system, the Computer Stored Ambulatory Record (COSTAR) system at the Harvard Community Health Plan, is designed for ambulatory care. The third system, the Problem-Oriented Medical Information System (PROMIS) at the University of Vermont Medical Center Hospital, is a developmental project that attempts to guide, as well as to support, the provision of medical care. The prototype operates in an inpatient setting, but the system is designed for use in any kind of medical care delivery site.

These three systems were chosen for discussion in this report because they represent different technical and conceptual approaches to handling information and are considered exemplary by professionals knowledgeable in the computer and medical fields. In no way does inclusion in or omission from this report support or criticize any system.

TECHNICON MEDICAL INFORMATION SYSTEM (TMIS)

El Camino Hospital in Mountain View, Calif., was the demonstration site for the Technicon system. El Camino, a 450-bed community general hospital with a medical staff of 340 physicians, serves patients under the care of their personal physicians. The hospital does not have an internship or residency program. It provides no outpatient services except diagnostic procedures for patients referred by staff physicians. It does have an emergency room.

The Technicon Medical Information System (TMIS) has been in operation at El Camino Hospital since 1972. Three years of development at the institution preceded the actual implementation. Implementation of the system throughout the hospital took 9 months. The Technicon Corporation and its predecessor, the Lockheed Corporation, bore the costs of development (over $25 million). The National Center for Health Services Research later awarded funds to El Camino Hospital for evaluation of the project.

System hardware, a large IBM computer, is located at Technicon's regional computer center, several miles from El Camino Hospital. A second IBM computer is available at the regional center for backup support. Data are maintained at the central processing facility using disks and tapes for storage. The hospital's 58 video and

31 printer terminals are linked to the computer center via high speed telephone lines. For the most part, software is written in assembly language, and COBOL is used for financial reports.

The Technicon Medical Information System is a hospital-wide system. It is designed to store patient data and send appropriate data, either upon request or automatically, to personnel who need them. Objectives of the system include more efficient hospital operations, improved patient care, and reduction or containment of hospital costs. A major goal of the system is to facilitate nursing activities.

Capturing Patient Data. Physicians, as well as nurses, ancillary service personnel, and admitting clerks, enter data through video terminals, which consist of a television screen, a keyboard, and a light-pen for rapid selection of information presented on the screen. Direct use by physicians distinguishes TMIS from several other hospital-wide systems. Alternatively, nurses can enter data for physicians. Terminals are located at each nursing station and in ancillary service departments. Each authorized person gains selective admission to the system by typing a unique identification code on the keyboard. This procedure ensures that hospital personnel can enter and obtain only information appropriate to the performance of their jobs.

The television screen displays a list of items, for example, laboratory tests that the physician might wish to order (see figure 2). A specific item is selected and entered into the computer system by pointing the light-pen at the desired phrase and pressing a switch on the barrel of the pen. Using the light-pen, a physician can enter a full set of medical orders (laboratory work, medications, X-rays, diet, activity, etc.) for a specific patient. The displays remind physicians to make orders complete; for example, when a medication is ordered, the display notes the need to specify scheduling and method of administration (oral, intravenous, or intramuscular) in addition to dosage. The keyboard may be used to enter any information that is not displayed in the display frames. TMIS prints copies of new orders for verification by the physician or nurse at the nursing station and automatically routes the orders to the appropriate hospital department (see figure 3). Orders to be carried out in the future are held in the system until the time designated.

Nurses use the system to enter physicians' verbal or telephoned orders, to report vital signs, and to record medications administered. Nurses must indicate by light-pen selection whether an ordered medication has been administered and, if it has not, provide a reason. Several nursing stations are experimenting with a computerized plan for nursing care that enables nurses to enter their patients' actual and potential problems and prognoses as well as nursing orders.

Other personnel also use the system. Admitting clerks enter a complete admission record through the video terminals. Clerks or technicians in ancillary services enter patient data. For example, clerical personnel type in dictated radiologist reports in the X-ray department. Results of high volume laboratory tests are entered by linking automated laboratory instruments directly to the TMIS computer.

Retrieving Patient Data. Once data are entered into the system, authorized personnel can review them immediately on the videoscreen terminals. Printer terminals also provide paper copies (printouts) at the nursing stations and in the ancillary service departments. The video terminal can display all data that have been entered from any point in the hospital up to the moment of retrieval.

Figure 2–TMIS Laboratory Test Order Display

```
KEFZOL INJ 500 MG, STAT, &THEN, Q6H
SMA-18.....  ______________________________
              COMMON LAB TESTS
              ----------------            ▶A
 BL CHEM      HEMA              OTHER     ▶B
 -------      ----              -----     ▶C
✓MA-18        ACT(COAG TIME) UA           ▶DE
 ▶DESCRIP     CBC               VDRL      ▶F
BUN            ▶DESCRIPTION               ▶G
CPK,TOTAL     ESR                         ▶H
CREATININE    HEMOGRAM                    ▶I-K
ELECT(SMA-6) (INCL PCV)    ▶OCC BL-ST     ▶L
GLUC(FBS)     PLAT CT      ▶CULTURE       ▶M-O
GLUC(2HPC)    PRO TIME                    ▶P
LDH,TOTAL                                 ▶QR
POTASS                                    ▶S
SGOT                       ▶BL BANK       ▶T
URIC ACID     ▶TESTS BY SPEC'M TYPE       ▶U-Z
(---------------------------------------------)
(PICKUP)      ▶PICKUP SCHED  ▶NURS
TOMORROW      ▶PRIORITY      ▶MEDS  ▶SPEC'M
TODAY_______SPM_COLLECTED__▶DIET__▶MASTER
  RETURN                            REVIEW
ERR           TYPE      RETRIEVE
```

SOURCE Technicon Corp

Physicians and nurses can retrieve the following information about their patients: admissions data, laboratory test results, X-ray reports, medications given, current orders, all orders since admissions, nursing notes, diagnoses, and allergies. Information in any category can be broken down to isolate desired data as, for example, cumulative results of a specific laboratory test. In addition, before each nursing shift, TMIS prints out a Patient Care Plan for each patient that lists all current orders to be carried out during that shift (see figure 4). "Medications due" lists are printed automatically throughout the shift.

Physicians can also obtain displays on general medical information compiled by staff physicians. TMIS currently stores information about subjects of interest in approximately 2,000 display frames. The "medical library" includes such information as abstracts of current articles from surgical journals, lists of antibiotic sensitivities, and interpretative aids for laboratory test results.

Communications, Administrative, and Business Functions. TMIS routes orders from nursing stations to the clinical laboratory, pharmacy, radiology, and dietary departments. At the same time that orders are printed in the pharmacy, the sys-

Figure 3–TMIS Printout of New Orders

```
Ø3-16-72 12:11 PM
                                NEW MEDICAL ORDERS
MILES. NELSON APPLETON          M  86          18391925
   BED: 249B     N/S: 2NORT    SERV: SURG    CHILDS. W
   PRIMARY DIAGNOSIS: GALL BLADDER
   ENTERED BY: CHILDS. W
   TIME ENTERED: Ø3-16-72 12:1Ø PM

      X-RAY:  GALLBLADDER- USE STANDARD PREP #7-

      IPPB. AIR DILUTION

      ACTIVITY. AMBULATE

      DIET. REGULAR

      VITAL SIGNS. T-P-R/BP. Q3ØM

      IV'S  START  D5/RINGERS. 1ØØØ ML. INFUSE OVER 8HR. THEN DC IV:
      ADD TO IV BOTTLE. COMPAZINE-INJ.1ØØMG.IN IV

      CBC

      UA

      VDRL

      SMA-12  (PREP #1)

      DIGOXIN-Ø.25MG. IM. STAT

      SECONAL-INJ:   SECOBARBITAL-2ØMG. IM. QID  (Ø3/16 Ø1PM-..)

      SECONAL-INJ:   SECOBARBITAL-2ØMG. IM  MR X1 FOR SLEEP


                                       ------------------------------
                                          DR. CHILDS. W

                                 NOTED ------------------------------
  -*-
```

SOURCE Technicon Corp

Figure 4--TMIS Patient Care Plan

```
06-06-72 12:53 PM

                         PATIENT CARE PLAN
                         -----------------
                FROM  7:00 AM 06-06-72 TO  3:00 PM 06-06-72
MUELLER. BERTHA                          F    72     796755
BED 205      N/S: 2WEST     SERV: MED     DR GRAMS.S MD
DX: DIFFUSE PULM. EMPHYSEMA
TO VISIT DOCTOR'S OFFICE IN: TWO WEEKS

VITAL SIGNS:
----- ------
   05-22  18.  V/S. BP-LYING. QID
   05-22  23.  VITAL SIGNS. BP-LYING

DIET AND FLUID BALANCE:
---- --- ----- --------
   05-31  51.  RECORD I & O

HYGIENE/ACTIVITY/SAFETY:
-----------------------
   05-21   2.  ACTIVITY. BEDREST-BRP
   05-24  27.  ACTIVITY. AMBULATE AS TOL

MEDICATIONS:
-----------
*  06-02  56.  RENEW TETRACYCLINE.CAP-250 MG. #1.PO. QID. (06/02 05PM-
               ..)      9  1
*  06-02  57.  RENEW ALDACTAZIDE-TAB. #1.PO. BID. (06/02 05PM-..)     9
*  06-02  58.  RENEW ASPIRIN.TAB-300 MG. #1. PO. Q4H. (06/02 05PM-..)
                9  1
*  06-02  59.  RENEW SECONAL.CAP-100 MG. #1. PO. QHS. (06/02 09PM-..)

*  06-02  60.  RENEW LIBRIUM.CAP-10 MG.. #1. PO. QID. (06/02 05PM-..)
                9  1
M  06-02  61.  RENEW MELLARIL.TAB-25 MG.. #1. PO--HS PRN (MISC MED)
*  06-02  62.  RENEW ELAVIL.TAB-10 MG. QID. (06/02 05PM-..)      9  1

OTHER DEPT.:
----- -----
   05-21  10.  IPPB. 40%. QID. LENGTH-RX 15MIN.
   05-21  11.  PHYS MEDICINE
   06-01  54.  RENEW EKG-STANDARD
   06-01  55.  RENEW LUNG SCAN- USE STANDARD PREP #28-

MISC. ORDERS:
----- ------
   06-05  63.  DISCHARGE PATIENT TODAY IN AM

PT CARE PLANNING:
-- ---- --------
   05-21       DENTURES: FULL
   05-21       PT WEARS GLASSES
   05-21       ALLERGIC TO NOTHING
   05-21       EXISTING COND:--C/O SOB

                                (LAST PAGE)
 -*-
```

SOURCE TechniconCorp

tern automatically produces labels for medications. Worksheets are printed for each ancillary service department; for example, the laboratory periodically receives lists of specimens to be picked up from patient care areas. TMIS automates the administrative tasks of admitting, transferring, and discharging patients. The system also provides reports on current bed status, that is, occupied and unoccupied beds.

A comprehensive business subsystem is part of the total TMIS system. The computer system automatically generates charges for services and supplies ordered and bills patients. It also provides for accounts payable, general ledger, budgetary control, inventory control, employee payroll, labor distribution, and workload statistics.

Patient Record. The individual patient's medical record is composed of both computerized and noncomputerized sections. Physician orders, cumulative medications, laboratory and X-ray reports, postoperative summaries, and admitting and discharge records are computerized. Printouts are produced for the paper medical record. Physicians' progress notes, most nursing notes, patient history, physical examination, and other materials are still recorded manually. The paper medical record, including the portions printed by TMIS, is maintained by the medical record department.

Patient data are stored in the active computer data files for 48 hours after a patient's discharge. These data are then transferred to magnetic tape for permanent storage. However, at present TMIS has no capability for long-term retrieval of an individual patient's record. (The Technicon system has incorporated this capability at several other hospitals.) A new computer record is started if the patient returns for another hospitalization. The paper medical record is used for pertinent information on previous care.

Priorities. Although TMIS has been operational at El Camino Hospital for the past 5 years, both hospital and Technicon personnel consider the system as, in many respects, still being developed. Priorities for new applications of TMIS at El Camino Hospital include:

- medical care and nursing audits;
- management functions, such as patient scheduling for ancillary services and optimal nurse staffing; and
- information to help physicians reach clinical decisions.

COMPUTER STORED AMBULATORY RECORD (COSTAR) SYSTEM

The Harvard Community Health Plan (HCHP) in Boston, Mass., is a prepaid group practice of 50,000 members that provides comprehensive medical care, including medical, surgical, and nursing services, laboratory and X-ray facilities, and emergency care. Since its establishment in 1969, HCHP has collaborated with the Laboratory of Computer Science (LCS) at the Massachusetts General Hospital to develop and implement COSTAR at its Kenmore Center facility. Costs for development during the first 5 years of operation were $2.5 million (23). Development of the system was supported by Federal grants. Currently, operational costs are paid by HCHP. The Laboratory of Computer Science has been responsible for the technical support of COSTAR. However, HCHP has recently decided to assume complete operation of the system in the near future.

The computers used in the COSTAR system are medium-sized Digital Equipment Corporation computers, located at LCS. Data are stored on moving head disk storage units. Application programs are written in MUMPS, a high level computer language designed by LCS. Over 30 video terminals and 3 printer terminals are located in the HCHP facility.

The Harvard Community Health Plan uses COSTAR to provide most of the information it requires for both patient care and program management. The system is primarily designed to improve the availability of information for patient care with modest increases in cost. It also is used to assess quality of medical care and to carry out administrative functions.

Capturing Patient Data. Medical personnel are not themselves required to enter data into the computer. Instead they enter data on a sheet of paper called an encounter form at the time of a patient visit. Clerical staff use video terminals in the medical record department to enter all data from the encounter forms into the computer, Because items are preceded on the encounter form, these clerks do not need to extract appropriate data, and problems of transcription are minimized. By checking off items on the encounter form, the provider (either a physician or nurse) records the patient's problems, medications or other therapies, and disposition. Different encounter forms have been specifically designed for each of the major specialties. Information on the forms is organized according to a carefully defined and limited vocabulary (see figure 5).

The physician or nurse can add a line of text to any of the coded entries. To add more detailed comments, the provider can dictate findings regarding a problem. All additions will be associated with that problem and appear with it whenever the record is produced. For an initial health assessment or a routine checkup, the provider records the patient's vital signs and completes a checklist of demographic data. Including a brief statement about the patient's personal and social background is also an option. X-ray and electrocardiogram reports are recorded on separate encounter forms. Laboratory test results are entered through a terminal located in the clinical laboratory.

Retrieving Patient Data. The medical record department enters appointment lists for each provider into the computer. For **each** patient, COSTAR automatically produces a paper printout of summary data that is distributed to the physician prior to the scheduled appointment. The information included in the summary depends on the specialty group to which the physician belongs. A limited amount of text about each diagnosis is always included in the summary. For visits to some kinds of specialists, extensive text about the patient's major problems is also included.

The basic printout is a Status Report on the patient and includes (see figure **6):**

- identification data;
- up to three lines of background information;
- a problem list with the total number of visits for each problem and the date of the last visit;
- current and past medication therapy;

Figure 5–HCHP Encounter Form for the Internal Medicine Department

4) SITE
A____ MH-PH
B____ CAMBRIDGE
C ✓ KENMORE
D____ KEN. TRIAGE
E____ CHMC
F____ PBBH
G____ BLI
H____ BI
J____ HOUSE CALL
K____ OTHER ________

5) TYPE
A ✓ SC SCHEDULED
B WALK-IN
C TEL E PHONE
D____ CANCEL LEO
E DNK
F____ CALL-IN
G____ IN-PATIENT
H EW
I NON-ENCOUNTER
J GROUP

NAME: Record, Sample Enr
UNIT: Ø7-39-Ø7 I
DATE: 4/4/75 DOB:
PROV #1: Plotkin
PROV #2: Imbernino
(if seen)
ABOVE MUST BE COMPLETE FOR INPUT

6) Hospital or EW Visit Approved: _ Yes _ No

************ THIS INFORMATION FOR FIRST VISIT PRIMARY PROVIDER ONLY ************

7) PRIMARY MD Plotkin 8) PRIMARY RN Imbernino
9) RACE: A X CAUCASIAN B BLACK C SPANISH SPKG D OTHER ________
10) MAR.STATUS: A SINGLE B X MARRIED C WIDOWED D____ SEPARATED E____ DIVORCED
11) # OF CHILDREN ∅ 12) PT. OCCUPATION Staff acct. - Boston based consulting firm

PERSONAL BACKGROUND OF PATIENT - Only for primary providers
(To change, rewrite entire section; max. three lines. Do not repeat above data.)

Pt is a fairly active person, generally healthy and feeling well. More physically active in summer - tennis, swimming. Commutes from southern New Hampshire during summer

************ TO BE COMPLETED FOLLOWING EACH VISIT ************

40) DISPOSITION
Future appt w/ ________________ in
(provider's full name)
A____ DAYS B____ WEEKS C____ MONTHS D____ PRN
E____ PT to call MD G____ PT to call RN
F____ MD to call PT H____ RN to call PT
I____ Other ________________

REFERRALS
42) INTERNAL HCHP CONSULTATION
Consultation w/ Urology # L993
(enter specialty and provider's last name, if specified)
Consultation w/ ________________
(enter specialty and provider's last name, if specified)
(IF A CONSULTATION NOTE IS NECESSARY, INCLUDE REASON FOR CONSULT IN ROUTINE DICTATION)

43) REFERRAL TO OUTSIDE AGENCY - NON-HOSPITAL
____
enter full name & address of physician and/or agency)
DOCUMENTS TO BE FORWARDED : ________________

44) HOSPITAL ARRANGEMENTS (make a choice in each column)
A____ BETH ISRAEL
B____ PBBH
C____ BOSTON HOSPITAL FOR WOMEN
D____ CHMC
F____ UNAFFILIATED

1.____ EMERGENCY WARD
2.____ URGENT ADMISSION
3.____ SCHEDULED ADMISSION
Date of Admission (if known) ________

45) SUPPORTIVE SERVICES
A____ HOMEMAKER C____ HOMECARE
B____ VNA D____ TRANSPORTATION

46) DICTATION ________
47) REVIEW OF CHART ________

48) FOLLOW-UP IMPORTANT ________

(continued)

Figure 5 **(continued)**

INTERNAL MEDICINE DIAGNOSES & PROBLEMS

(M=Major, O=Omit from Status Report, P=Presumptive, S/P=Status Post, R/O=Rule Out, I=Place on Inactive List. Simple check=minor)

60, Height 69 ins. **61. Weight** 170 **lbs. 62. Pulse/Min** 72 63. Temp. ______

64. Blood Pressure 1. 120/75 2. ______ 3. 4. ______ 5. ______
(state whether lyingstanding, sitting, etc.

GENERAL

✓	A6ØØ	IHA generally healthy P.E. WNL
	A8ØØ	PHR
	A99Ø	Dx deferred (state features)
	A8Ø1	No demonstrable disease (explain)
	A8Ø2	Exam for certificate
	A128	Rx refill only
	AØØ3	Immunization only
	A8Ø3	Test results only
	AØ19	Positive family Hx (specify)
	A81Ø	Health education
	AØ2Ø	Abnormal t. result (specify)
	A8Ø4	Lab test not performed (specify)
	A811	Pt. left without being seen
	A812	Pt. refused Rx (specify)

THYROID

	B21Ø	Goiter
	B151	Hyperthyroid
	B152	Hypothyroid
	B153	Thyroid nodules(s)

ENDOCRINE METABOLIC

✓	A15Ø	Obesity would like to lose at least 10#
	B12Ø	Diabetes mellitus
	B18Ø	Hypoglycemia
	B16Ø	Hypercholesterolemia
	BØØ5	Hyperlipoproteinemia
	B178	Hyperuricemia
	NØ11	Gout

URINARY

	L1Ø1	Urinary tract infection
	L1ØØ	Bacteruria, asymptomatic
	L29Ø	Urethritis
	L22Ø	Benign prostatic hypertrophy
M	L993	Hematuria

OTHER DIAGNOSES

S/P	ODØ1	Appendectomy - 1957
	ODØ2	
	ODØ3	
	ODØ4	

FREE TEXT COMMENTS ON DIAGNOSES, PROBLEMS & PROCEDURES

DIAGNOSTIC CODE	Comments (6Ø characters each)
1. L993	No previous hx prior 1 wk. In process of evaluation
2.	
3.	

SOURCE Laboratory of Computer Science, Massachusetts General Hospital

- laboratory test and X-ray results; and
- consultations requested but not yet recorded.

The individual provider can request data in other formats as well, such as the report of a previous visit, laboratory results not associated with a previous visit, or a flowchart of a particular problem, laboratory test, or medication.

In addition to the printed record, videoscreen terminals located in every area of patient care allow the provider to obtain immediate access to any part or all of the computer record. The video terminal is most often used for reviewing an extensive record or obtaining information about patients without scheduled appointments. Entry to terminals does not require a password or other identification. However, they are located in areas where they can be monitored by professionals.

Administrative and Business Functions. Managerial requirements for data at HCHP are determined by both its organization as a prepaid plan and its highly mobile population; there is a 20 percent membership turnover each year. COSTAR provides data on current enrollment, certification of claims, and appointments. The computer produces a variety of administrative reports and statistical analyses for reviewing utilization, budgeting, and manpower and facility planning. Although COSTAR itself produces bills for the few patients who pay fee-for-service, other computer systems perform business services such as cavitation billing, payroll, and financial reports.

Patient Record. The COSTAR system stores all patient data generated at HCHP. Parallel information is not kept in a paper medical record. The medical record room maintains files, however, for copies of letters or discharge notices from other physicians or hospitals, electrocardiogram tracings, and other materials that are not computerized. Patients' records are stored on computer disks in the COSTAR system indefinitely for all current members. For permanent storage, former members' records are put on disks that are not connected to the central processing unit.

Priorities. HCHP's priority is to expand its use of COSTAR for reviewing the quality of medical care given to patients. Under a current experimental program, COSTAR monitors the data files of patients with several specified conditions, Standards for treatment were developed by a committee at HCHP and programed into the computer. If the care being given deviates from these standards, reminders are printed out to physicians. Work is in progress to add computer protocols for additional medical treatments. HCHP also plans to duplicate the COSTAR system at another HCHP facility in Cambridge, Mass.

PROBLEM-ORIENTED MEDICAL INFORMATION SYSTEM (PROMIS)

The demonstration site for PROMIS is the Medical Center Hospital, a 450-bed teaching hospital at the University of Vermont in Burlington. The PROMIS Laboratory, located at the University, designed and implemented the system. Development began in **1967,** and PROMIS was installed and used in a 20-bed gynecology ward in the hospital from 1971 to 1975. During the 4 years of its operation on the ward, PROMIS was also implemented in the ancillary service departments most frequently used: radiology, the clinical laboratory, the pharmacy, and in the doctors' lounge where surgeons entered their notes after operations. Secretaries on the ward acted

Figure 6–COSTAR Patient Status Report

```
                         RECORD,SAMPLE ENR-(M)
EFF 1/75            PRIMARY MD PLOTKIN        07-39-07-I
GRP FFS             PRIMARY RN IMBERNINO      56 YRS.-DOB:1/2/1919

LCS MGH,BOSTON 02109 TEL:726-3933
RACE:CAUCASIAN
MAR STATUS:MARRIED
# OF CHILDREN:0
PT OCCUPATION:STAFF ACCOUNTANT, BOSTON BASED CONSULTING FIRM
PT IS A FAIRLY ACTIVE PERSON, GENERALLY HEALTHY AND FEELING
WELL.  MORE PHYSICALLY ACTIVE IN SUMMER - TENNIS, SWIMMING.
COMMUTES FROM SOUTHERN NEW HAMPSHIRE DURING SUMMER.  4/4/75

9600  INITIAL HEALTH ASSESSMENT  GENERALLY HEALTHY, P.E. WNL
                                         4/4/75 (PLOTKIN: M.D.)


MAJOR PROBLEMS
1993 HEMATURIA NO PREVIOUS HX PRIOR 1 WK. IN PROCESS OF EVALUATION
                               4/1/75-2-4/4/75  (PLOTKIN: M.D.) #D


MINOR PROBLEMS
A150 OBESITY WOULD LIKE TO LOSE AT LEAST 1o POUNDS
                                       4/4/75  (PLOTKIN: M.D.)
P666 TOBACCO ADDICTION 1 PACK PER DAY   4/4/75 (PLOTKIN: M.D.)


INACTIVE PROBLEMS
S100 S/P APPENDECTOMY 1957              4/4/75 (PLOTKIN: M.D.)


CURRENT THERAPY
R010 FLUIDS 8 GLASSES PER DAY          4/1/75 (GOLDSMITH: R.N.)


TEST RESULTS
4/4/75   R070  PYELOGRAM (IVP)
                NORMAL, NO EVIDENCE STONE, CALYCES NORMALLY VISUALIZED
         N204  URINALYSIS INCL MICRO  10-20 RBC/HPF  (2) #A
4/1/75   B100  URINE CULTURE       NO GROWTH
         A156  WHITE BLOOD COUNT   8900
         A128  HEMOGLOBIN          14.1
         A127  RBC                 4.4
         A126  HEMATOCRIT          39

CONSULTATIONS AND REFERRALS
UROLOGY 4/4/75 (PLOTKIN) FOR L993

. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
```

SOURCE Laboratory of Computer Sciences Massachusetts General Hospital as intermediaries for departments that were not included in the computer system.

Hardware used when the system operated on the gynecology ward included two large Control Data Corporation computers and 14 touch-sensitive video terminals. Program languages (MACRO assembly, HIP, and SETRAN) developed by the Control Data Corporation were used. The PROMIS staff itself did the application programing. The entire system was updated by the PROMIS Laboratory in 1975 and implemented on an internal medicine floor at the end of 1976. The new system uses Varian minicomputers and high-speed Megadata touch screen terminals. Data are maintained on disk storage. Application programs are written in PPL, a new language developed by the PROMIS Laboratory.

Support for development of PROMIS has been provided under grants, and currently a contract, from the National Center for Health Services Research. Total funding through FY 1976 was approximately $4 million. Additional resources have been provided by the Robert Wood Johnson Foundation and the University of Vermont College of Medicine.

Capturing Patient Data. PROMIS is unique in two respects. It not only radically restructures the medical record, but also directs the process of clinical care. The PROMIS Laboratory staff developed these capabilities in order to address problems hindering the provision of medical care: dependence on the physician's memory, ineffective organization for massive amounts of medical data, and lack of meaningful feedback about the appropriateness of care.

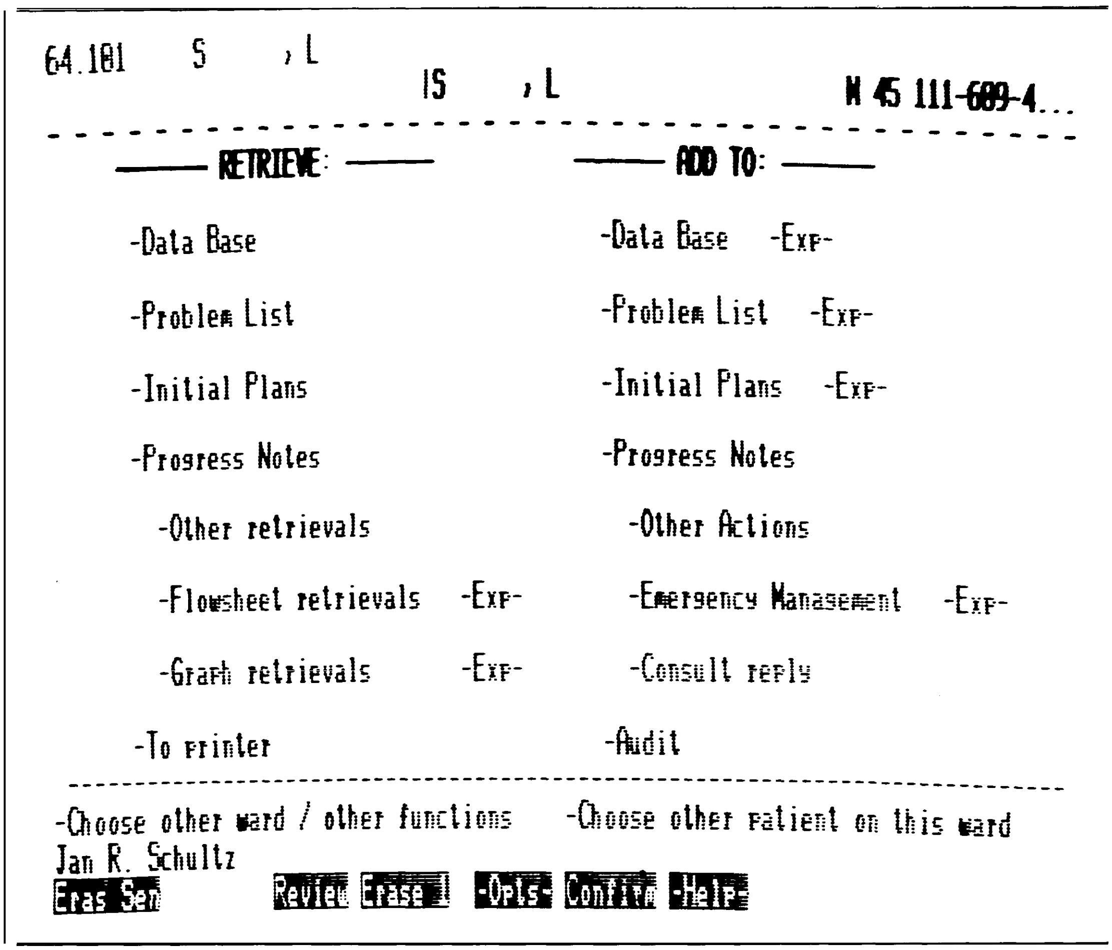
In PROMIS, data are organized by patient problem. The computer record is structured around four phases of medical action: an initial data base on each patient, including medical history and physical examination; a list of the patient's problems; diagnostic and treatment plans for each problem; and *progress notes* on each problem indicating how the patient is progressing during therapy. Except for the initial data base, every entry into the computer record is associated with a particular problem of the patient. Thus, when a technician enters the result of a laboratory test, the data are entered under the problem for which the test was initially ordered. By structuring the record in this way, all information pertinent to a problem is organized logically for review by the physician and other medical care professionals.

Personnel enter data about patients through video terminals. The videoscreen of the terminal displays an array of choices, and the provider makes a selection by touching the screen. Data are entered by the medical care professionals who originate them. For example, physicians and nurses enter notes about the patient's progress, radiologists enter notes as they read films, and technicians in the clinical laboratory enter results of tests. In addition, patients enter their own medical histories. Each staff member has a unique identification code that allows entry and access only to those parts of the computer record necessary for the provision of care.

PROMIS guides these medical care professionals in structuring the vocabulary, content, and organization for the patient computer record. This guidance is accomplished through the display frames viewed on the videoscreen that providers use to enter data. Sequential frames are displayed according to logic algorithms (decision trees) programed in PROMIS. The information shown in a particular frame depends on the choice selected in the previous frame. The answers a provider gives to questions, not the providers themselves, determines what frame appears next. The display frame sequences guide the provider through logical pathways and ensure that notes and orders are complete.

The videoscreen first shows the provider a master frame (see figure 7). From this frame, the provider selects a category of information and chooses whether data are to be added or retrieved from the computer patient record. To enter information about a new problem, for example, a physician would touch' 'problem list" from the "add to" column. A system of the body, cardiovascular for example, is then chosen. The subsequent frame would show possible diagnoses for the cardiovascular system (see figure 8A). If "hypertension" were chosen from the list of possible diagnoses, the frame shown in figure 8B would appear to request more information. This communication between the physician and display frames would continue until a complete narrative description of the problem had been generated. Figure 9 shows such a narrative that has been retrieved on the problem "cirrhosis. "

Figure 7– PROM IS Master Frame



SOURCE PROMIS Laboratory

Figure 8– PROMIS Display Frames for Entering Data About a Patient Problem

8A

```
73.2888    S      , L
IS      , L          . . . . . . . . . M 45 111-689-4... IAdd a Major Active Problem: .
- - - - - - - - - - - - - - - - - -Cardiovascular - - - - - - - - - - - - - - -

 -- Common diagnoses --                      -- Diagnoses by anatomic site --
   -arterioscl. periph. vasc. disease,         -entire heart

   -digitalis intoxication,                    -conduction system

   -heart failure,                             -coronary arteries

   -hypertension,                              -heart valves and endocardium

   -myocardial infarction, acute,              -myocardium

   -myocardial infarction, remote,             -pericardium and pericardial space

                                               -pulmonary arteries

                                               -pulmonary veins

                                                                   -More Chcs-
Jan R. Schultz
Eras Sen        Review Erase 1  -Opts-        -Help-
```

80

```
73.18        S       , L
         . . . . . . . M 45 111-689-4... IAdd a Major Active Problem: Hypertension,
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


      -systolic,

      -diastolic,

      -combined,







Jan R. Schultz
Eras Sen        Review Erase 1  -Opts-        -Help-
```

SOURCE PROMISLaboratoty

Figure 9–PROMIS Narrative on a Patient Problem

```
#####    RETRIEVE    ##### S    , L        .  PAGE 1

Retrieve 'abstract' for an active problem:  4. ->cirrhosis, portal
    (Laennec's), onset [unknown diagn...

4. ->cirrhosis, portal (Laennec's), onset      /RM Cxxxxxxx CC3  04/26/77 11:12
   [unknown diagnosis confirmed bx 1976 ]
  Current condition: serious, and stability    /LJ Bxxxxxxx LPN  04/29/77 08:01
    not known at this time. Condition is worse than expected considering
    available data.
  Current aims for problem management:
   Goal: Limited to managing 'sickness'       /PA Pxxxxxxxx CC2  04/25/77 22:22
     produced by problem, because no other actions available at this time.
   Objectives during hospitalization:
     [reduce edema]
   Objectives during other interval:  -- no entries --
   Priority: high.
   Person coordinating management:  -- no entries --
   Limits to management options:
     In following course:                                   04/28/77 10:03
       [Patient is difficult to arouse this A.M.; will not take deep breat
        hs, nor will he raise sputum from below trachea.]
   Other: Patient agrees with Aims. Attending agrees with Aims. 04/25/77 22:22
                               Return                          Next Page
```

SOURCE PROMIS Laboratory

Along with the sequenced display frames that guide medical care personnel in entering data about the patient, PROMIS supplies display frames that present medical knowledge. Only medical knowledge appropriate to a specific problem and clinical action is shown because "medical content" frames are carefully programed and integrated with data entry frames.This integration ensures that physicians receive medical knowledge automatically.

When the physician orders a drug, for example, the ''medical content" frames would indicate such information as side effects, drug and test interactions, cost, and usual dosage. Display frames on laboratory tests list risks, normal ranges of results, costs, and contraindications. Medical content frames help to diagnose a particular problem by suggesting possible diagnoses and tests that would rule out some possibilities. Finally, medical content frames on treatment and follow-up care for particular problems or diagnoses give the physician options for action.

Medical content frames are rigorously researched before they are entered into the computer system. Recognized experts in the relevant field review the frames for completeness, accuracy, and currency. The display frames also include numbered references to medical literature available in the university medical library. Currently, the PROMIS "library" includes over **33,000** frames. Medical literature is constantly reviewed, and if recent articles dictate any changes, the PROMIS staff enters the new information on display frames.

Retrieving Patient Data. Patient data can be reviewed on the videoscreen terminals or on hard copy printed out by printer terminals. Because all data are linked to a particular problem of the patient, the information in the computer record is well-defined and structured. Data can thus be obtained by almost any parameter required. A physician can review progress notes by problem over time, a pharmacist can review current medications, and a nurse can obtain all outstanding orders by problem for each patient. A display frame showing a patient's current outstanding laboratory tests is shown in figure 10.

Communication and Administrative Functions. PROMIS routes messages between areas of patient care and ancillary service departments. Currently, PROMIS does not incorporate administrative functions, such as payroll and accounting. Because entries of procedures, services, drugs, and tests can be associated with charges, a business subsystem could be integrated into the computer system. The design of PROMIS could permit the addition of such functions as patient scheduling, automatic laboratory reporting, and other applications in the future.

Patient Record. All data that are recorded about the patient are stored in the computer record. In addition, because every entry shows date, time, and staff member who entered it, the process of medical care is clearly documented for future audit. Computer records are maintained indefinitely on disk storage. Because PROMIS was installed in only one service, paper medical records were also kept.

Priorities. PROMIS is still in the developmental stage, although it has been shown to be technically feasible. Priorities of the PROMIS Laboratory for the continued development of PROMIS include:

- implementing the system throughout a hospital;
- continued development, validation, and maintenance of the medical content display frame "library;" and
- incorporation of medical audits to ensure quality of care.

Figure 10– PROM IS Display of Outstanding Laboratory Tests

```
326.1818-a S      , L
           IIS    , L   . . . . . . . . M 45 111-689-4... |Lab test report:
-54--------------- Current Outstanding Lab Tests------ -Do x- -Ord- -Last Rpted-
13. ->heart failure, chronic, class Ionset in 1972.

     -Serum digoxin today                           [ 1]; 5/18;  not rpted
18. Hypokalemic alkalosis, onset in 04/77, predisposed to by 4. ->c...
     -Urine specific gravity daily                  [Sd]; 5/18;  5/18 18:46
19. Ascites, onset approximately in 1976, due to 4. ->cirrhosis, po...
     -Serum transaminases GPT every 4 days.         [Sd]; 5/07;  5/16 11:19

     -Urine occult blood each void                  [Sd]; 5/07;  5/18 18:46

     -[Spot urine K, Na] every 2 days.              [Sd]; 5/17;  not rpted

     -SMA 12/60 battery every 4 days, begin 05/22/77 [Sd]; 5/18; not rpted

     -Serum electrolytes (Cl, CO2, K, Na) and BUN every 4 days, begin 05/22/7-
       7                                            [Sd]; 5/18;  not rpted
     -Serum electrolytes (Cl, CO2, K, Na) and BUN today
                                                    [ 1]; 5/18;  not rpted
     -Hct every 4 days, begin 5 /22/77              [Sd]; 5/18;  not rpted

        -Erase Se-    -Erase 1-              -Next Frame-  -More Ches-
```

SOURCE PROMIS Laboratory

4.

IMPLICATIONS

4.

IMPLICATIONS

Medical information systems have important implications for the quality of patient care. Institutional errors can be substantially reduced and coordination improved. Clinicians can obtain guidance on appropriate diagnostic and therapeutic regimens while patients are still under care. Physicians can be freed from the burden of relying on fallible memory. Other medical professionals may perform new duties or acquire added responsibilities because they have been relieved of routine paperwork.

The extensive data base in medical information systems could supply aggregate health data collection systems with more accurate, easily accessible data than are now available. In addition, medical information systems could provide a new mechanism for assessing the quality of medical services provided, evaluating and planning medical care resources, and conducting epidemiological research.

Because medical information systems are designed for different kinds of settings and vary in scope and objectives, not all implications apply to all systems. Examples from the systems described in chapter 3 are given when possible to illustrate benefits and drawbacks and to differentiate between the proven performance of medical information systems and benefits that might be expected if the computer systems are developed further and become widely accepted.

INSTITUTIONAL DELIVERY OF PATIENT CARE

Evidence indicates that by facilitating communication and reducing errors, medical information systems improve the patient care delivered in medical care institutions. Some errors are reduced because computer systems help ensure that data about a patient are accurate, available, legible, complete, timely, and organized. Through *their mechanisms to check whether orders have been carried out, medical information systems also monitor performance and prevent some errors of omission.*

Avoiding Errors

Accuracy of patient data can be ensured by having the provider or ancillary service originating them verify all entries. Errors can thus be detected and corrected immediately at the source. Detecting an error later is more difficult because the relevant data are not readily available.

In TMIS and PROMIS, patient care providers and technicians enter data through videoscreen terminals and thus communicate directly with the computer system. After being typed in or selected by light-pen or touch, data are displayed on

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the videoscreen a second time for verification before being entered into the computer record. After the implementation of TMIS at El Camino Hospital, accuracy of medical orders and test results improved (7).

In the COSTAR system, clerks in the medical record department enter data into the computer from preceded sheets called encounter forms. An inhouse study at the Harvard Community Health Plan estimated the rate of transcription errors to be very low, less than 1 percent of the data items (5).

Availability of information can be ensured by giving many providers simultaneous access to the patient record from different locations. A manual medical record can be in only one place at one time. The three medical information systems described in this report make patient data available on videoscreen terminals located in various patient care areas. Printer terminals also produce and duplicate paper records.

Lost or mislaid records are a problem in ambulatory care settings. Records are estimated to be unavailable for as many as 10 to **20** percent of patient visits in some ambulatory care facilities (5). COSTAR eliminates this problem by providing a summary record in advance of each scheduled patient visit. Videoscreen terminals can give information to providers when they see patients with unscheduled visits, answer telephone inquiries, or need to review a complete patient record. In some areas of HCHP, however, a single terminal serves three physicians, three nurses and a receptionist, sometimes resulting in a queuing problem. At El Camino Hospital, one video terminal and sometimes two are located at every nursing station. Hospital staff did not indicate any problem regarding access to the terminals.

Legibility is an obvious advantage of medical information systems over manual medical records. Typed copy available on terminal screens or in computer printouts is easier to read than the typical handwritten note. Illegible handwritten entries in the paper medical record can cause delay or, if read inaccurately, may lead to inappropriate action.

Completeness of information can be ensured by entering all data that may be needed into a central computer patient file. In COSTAR and PROMIS, all data that are generated during the care of a patient are entered into the computer record. In addition, PROMIS automatically reminds providers to enter information essential to diagnosing a problem or carrying out orders. Questions and choices for answers are displayed in a sequence determined by answers to previous questions.

Computerized information about the patient is more limited in TMIS than in COSTAR and PROMIS. TMIS does, however, computerize all physician orders and the resulting reports from ancillary services. The frames used to write orders remind physicians to make their orders complete. After implementation of TMIS at El Camino Hospital, the number of medication orders that omitted site, scheduling, and method of administration decreased (7).

Timeliness of information can be ensured by entering patient data into the computer record as soon as procedures are performed or observations made. As hospitals have become more complex, the demands placed on ancillary services have increased, and communicating all the latest information has grown more difficult.

TMIS and PROMIS automatically update the patient's record so that it reflects the most current status. Reports and results are entered directly into the computer system from ancillary services. With electronic transfer, orders and tests need not be repeated because of poor communications. In addition, if the time between entering orders and learning results of tests and procedures is reduced, physicians can proceed quickly with further appropriate diagnostic or therapeutic procedures. The average length of stay at El Camino Hospital has been shorter since the introduction of TMIS. Staff have attributed this reduction to improved communications made possible by TMIS. Other factors, however, may also have contributed.

In COSTAR, new encounter data are usually entered into the system within 24 hours of a patient visit. Data are therefore available for the patient's next visit to the ambulatory care facility.

Organization of patient data enables providers to find necessary information more easily. In a manual medical record, information is often scattered among many pages of a chart that is usually arranged in chronological order and separated by source. Computerization allows a flexible arrangement of data, permitting the most effective use of patient data by the provider.

At El Camino Hospital, for example, a physician can retrieve the results of all laboratory tests on the video terminal. Cumulative results of tests are also available in paper printout. Because all information in PRO MIS is associated with a patient's particular problem, the physician can review progress notes, medications, laboratory results, and vital signs over time to determine if therapy is effective. At HCHP, a standard format used to provide a summary is routinely supplemented by flow charts and extensive visit notes on major problems of patients.

Monitoring for Errors

By monitoring for institutional errors, medical information systems further ensure that orders for the patient's care will be carried out. Noncompliance with physicians' orders is a severe problem in U.S. hospitals. An estimated 13 to 15 percent of all medications are not administered exactly as the physician ordered (SO). A study in one hospital found that 15 percent of ordered laboratory tests were never performed (45).

Each of the computer systems described in this report has mechanisms to monitor whether orders for procedures or medications have been carried out. If they have not, reminders are displayed or printed. Under TMIS, for example, lists of "medications due" are printed out hourly, and nurses must record in the system whether or not the medications are administered. After installation of the computer system at the hospital, total errors in administering medications were reduced about SO percent from the pre-TMIS period (7). Failures to give medications were almost completely eliminated. After TM IS, discrepancies between the orders for and actual scheduling of laboratory and radiological procedures were also reduced. No evaluations of other medical information systems have yet been conducted.

SUPPORT OF CLINICAL DECISIONMAKING AND PHYSICIAN EDUCATION

Medical information systems can offer support for clinical decision making, provide continuing medical education, and facilitate the spread of new medical knowledge. Several studies *indicate that er-*

rors of omission by physicians are reduced if timely reminders are provided by the computer systems, This capability has been more fully developed in one system than in others.

Supporting Clinical Decisionmaking

As students, physicians must memorize enormous numbers of facts. Throughout their careers, they are expected not only to remember this information, but also, as medical knowledge increases and grows more complex to add new information. The quality of clinical care often depends on the accuracy and completeness of the physician's memory.

Computer systems can assist physicians by reducing the amount of material to be memorized. During clinical care, computer systems can instantaneously supply physicians with information about individual patients and medical knowledge from the literature.

The role of medical information systems in supporting clinical decisionmaking and continuing medical education may be either *passive* or *interventionist.* In a passive system, information stored in the computer is made available to physicians when they take the initiative to ask for it. Interventionist systems automatically supply appropriate information to physicians and other medical professionals.

The "mini-library" of frames displaying medical information incorporated into TMIS at El Camino Hospital exemplifies a medical information system taking a passive role in continuing education. Medical information frames in TMIS are independent of data entry and retrieval frames. They may be reviewed whenever, but only when, the physician chooses to do so.

Computer systems have been developed to support some kinds of clinical decisions. Such subsystems could be integrated into medical information systems like TMIS. For example, a system developed at Beth Israel Hospital in Boston can classify a patient's acid-base abnormality and through a series of questions to the physician, recommend appropriate therapy. Another computer project called HELP (Health Evaluation through Logical Processing) has been developed by the Biophysics Department at the University of Utah (43). HELP stores data about patients from terminals in such areas as the coronary care unit, the postoperative intensive care unit, and the pulmonary function laboratory as well as data from a computerized patient history and laboratory screening. Using these data and algorithms based on arithmetic and logic statements, HELP can automatically generate a list of options for treating an individual patient, Other projects include computerized protocols for managing on an outpatient basis certain diseases, such as hypertension, diabetes, and kidney stones (49). These systems to support clinical decisionmaking use a computer's capacity for complex analysis and manipulation of data, but they are nonetheless passive systems because the physician must elect to review the medical information they have stored.

Interventionist systems, in contrast, are programed to provide medical data automatically when they are needed for patient care. Such systems monitor the acceptability of care while the patient is being treated. They are based on an assumption that physicians are not likely to stop and ask a computer for information, but would use information automatically supplied.

This capacity exists to some extent in all three of the computer systems described in this report.

- In TMIS, computer printouts highlight abnormal laboratory test results in heavier ink and large characters.
- In COSTAR, computer programs for selected diseases or clinical symptoms identify followup care that has been omitted. These programs automatically notify physicians of the recommended procedure for their patients.
- In PROMIS, medical content frames are combined with data entry frames. Drug sequences provide information on specific drugs. Test or procedures frames include such information as cost, limits of normal, and producibility. "Rule-out" frames show why and how certain diagnoses can be ruled out as causes. Decision trees, which physicians are required to use, incorporate the entire spectrum of medical knowledge.

This capability of the computer systems to supply appropriate medical information frees the physician from reliance on memory and allows concentration on tasks that are uniquely human. Although the computer may be better suited to processing the multitudinous data necessary for diagnosis and treatment, the physician is responsible ultimately for decisions on patients' care.

Interventionist systems might be expected to improve the quality of patient care by reminding physicians of relevant data and facts. Results of the experimental program at the' Harvard Community Health Plan are encouraging (6). After implementation of the program providing automatic feedback, there was a statistically significant improvement in followup treatment of patients with sore throats. Improvement in the followup care of hypertensive patients occurred when repeated reminders were sent.

Several other studies conducted at Indiana University by the Regenstrief Institute indicate that *use* of computer protocols in ambulatory care reduces errors of omission by physicians. One study, conducted in an adult diabetes clinic, evaluated the effect of computer intervention to several medication-related clinical events (31). It found that physicians responded to 36 percent of the clinical events with computer reminders and only 11 percent without. A second, more extensive study, using 390 computer protocols dealing with conditions managed by drugs or induced by drugs, was conducted in a general-medicine clinic of the same outpatient department (30). This study analyzed physicians' responses to computer recommendations for courses of action following certain clinical events. It found that those physicians given computer recommendations detected and responded to twice as many events as the control group of physicians. Further, physicians' response rate fell when they left the group receiving computer recommendations and joined the control group. The study thus concluded that the difference in response rate was due not to ignorance of appropriate procedure, but rather to the difficulty of contending with the informational loads of busy practice settings.

These studies give a preliminary indication that computer protocols for the clinical management of certain problems influence physicians' behavior. Further evaluations are needed to confirm these results.

If the role of computer systems in clinical decisionmaking increases in the future, medical education will change. Without the need to accumulate facts, students' education could emphasize the study of the processes involved in decision making, as well as the social and psychological aspects of medical care (48). Such an educational experience would prepare students to take a new role as clinicians.

Dissemination of New Medical Knowledge

Scientific journals report research on new therapies, procedures, and drugs. Incorporate ion of this "new" medical knowledge into the everyday practice of medicine depends in part upon physicians' reading journals and remembering results of studies at appropriate moments of medical intervention. As a result, medical *practice* does not always reflect current medical knowledge.

Medical information systems can disseminate new medical knowledge by incorporating the most recent medical information into computer programs. The burden of reading myriad journals shifts from busy practitioners to those responsible for maintaining and updating a medical information system's "library" of medical knowledge. In PROMIS, for example, new medical knowledge is added to the system as studies appear in the literature and is presented to physicians in the context of related problems, procedures, or drugs. The information is carefully researched before its entry into the system, and references to the source journal are given on the display frame.

The entry of new medical information that has not been carefully evaluated is a problem that may arise in the future. At present, developers of systems determine what information is entered in the prototype systems. As medical information systems are "packaged" for mass marketing, such control will be more difficult. If in every hospital, for example, unproven or experimental therapies were entered as options for medical care, regardless of their efficacy, the credibility of the medical information system would be considerably downgraded.

A system such as PROMIS, which attempts to incorporate the whole spectrum of medical knowledge into its guidance system, particularly runs this risk. To guard against it, the PROMIS Laboratory has suggested the establishment of "a central organization with the mandate to coordinate, control, and certify developmental and deployed systems" (54). The central organization, or "national repository of display frames," would be charged with developing, validating, and maintaining a library for medical content display frames. It would also offer technical assistance and supply updated display frames to user medical care institutions. One example of a public organization that might perform this function is the National Library of Medicine,

ASSESSMENT OF THE QUALITY AND UTILIZATION OF MEDICAL CARE

Medical information systems can *be programed to* help assess *the quality* of *medical* **care** *in terms of the care process. Appropriateness of inpatient facility use can also be monitored. These legally manda fed /uric/ions* could *be accomplished without the expense of an additional data collection system. No medical information system, however, is programed as yet for these purposes.*

Quality of care is usually assessed by judging the process of care, or those diagnostic and therapeutic services ordered for a particular problem, against an agreed upon minimum standard for acceptable care. Hospital peer review committees have carried out this retrospective monitoring of care for years.

The **1972** Amendments to the Social Security Act mandated that Professional Standards Review Organizations (PSROs) be established nationwide to review the quality and utilization of medical services provided to Medicare, Medicaid, and Maternal and Child Health patients. The PSROs are required to conduct studies of processes of care. In such a study, called a medical care evaluation, a diagnosis or procedure is chosen for study, a sample of patients selected, and the patients' records examined to determine if the care as recorded meets minimum standards established by the PSRO. Determining an appropriate patient sample and carefully examining records in a manual system can be time consuming and costly. A medical information system with patients' diagnoses and procedures accurately recorded and coded could facilitate such retrospective review. Data in a computer record are likely to be more complete and accurate than those in a manual record. Further, a medical information system could select samples of patient records for audit and, if properly programed, examine the records for compliance with standards.

No medical information system is presently used for medical care evaluations in a PSRO program, but the computer systems described in this report have the potential to fulfill this function. At HCHP, data are collected on structured, preceded forms. Because almost all data in the computer record are coded, COSTAR can be programed to monitor the record against predetermined standards of care or to retrieve records for manual audit by a given parameter. At El Camino Hospital, the major discharge diagnoses and procedures are coded in TMIS. Computer programs permitting medical audit are in the planning stages. Audit by problem, patient, or physician could be programed in PROMIS because all activities are linked to specific problems. In addition, the logic of the patient care process, that is, the reason for a certain procedure and the relationship of that particular step to preceding and following steps, is explicit in PROMIS. Medical auditors would not need to guess about the reasons for actions.

Professional Standards Review Organizations also monitor the utilization of medical care services. If medical information systems were programed to monitor the "appropriateness" of care in accordance with the requirements of the local PSRO, physicians could automatically be notified of any failure to meet criteria that justify keeping the patient in the hospital another day. Because medical information systems can process and return data as soon as they are entered, such notification could be given in a more timely fashion than is possible with a manual system. Having medical information systems screen for appropriate utilization could therefore be more effective than manual systems and could be accomplished without the cost of an additional system to collect and process data.

MALPRACTICE LITIGATION

Whether medical information systems would increase or decrease malpractice litigation is debatable. Computerized medical records document the conduct of medical therapy. They could eliminate some causes of litigation by reducing errors in patient care. Errors that do occur could be highlighted however, and lawsuits increased.

A patient's record is often the most important piece of evidence in any medical professional liability suit (25). As a deviation from accepted standards for properly documenting and maintaining records of treatment, a poor record itself constitutes an act of negligence in the eyes of the court (29).

Computerization of the medical record ensures a legible, orderly, and readily available record and could, therefore, document proper and careful conduct of medical therapy. Because medical information systems tend to reduce errors in patient care, litigation may decrease. Errors caused, for example, by poor communications, overlooked positive laboratory results, and improper administration of medications are substantially reduced through use of computer systems. Systems that incorporate medical care audit programs or guidance systems during the care process could also eliminate some causes for litigation. Adherence to the established guidelines provided in the systems might be an effective defense for physicians and a possible deterrent to the filing of suits.

On the other hand, errors that do occur could be highlighted in the computer record, and the number of malpractice lawsuits increased (34). In addition, legal problems may arise because the computerized patient record differs from that in the average medical practice. Until computer records are accepted as consistent with standards for documentation, they might not constitute legal evidence in malpractice cases. Finally, critics argue that the art of medicine cannot be confined to standardized therapies incorporated as guidelines into a medical information system. A physician who deviates from such guidelines might be in jeopardy of a lawsuit and forced to justify the actions taken.

No data are available from institutions that use medical information systems on rates of malpractice suits before and after implementation of their computer systems. Contentions that the systems would increase or decrease litigation are, therefore, speculative.

ROLES OF MEDICAL CARE PROFESSIONALS

Medical information systems allow an upgrading of job responsibilities by permitting medical care professionals to make full use of *skills. However, there is insufficient evidence to conclude that personnel actually perform new duties or that their productivity increases in activities related to patient care.*

Medical information systems reduce or eliminate paperwork at the same time that they make available information needed for optimal job performance. Pharmacists, for example, can review medication orders for potential drug interactions if they are freed from typing medication labels, have computer-produced medication schedules and worksheets, and can obtain patients' medication profiles. Nurses have the opportunity to spend more time caring for patients if they no longer must spend hours performing clerical tasks. The head nurse who has more time for administrative duties and can analyze computer-produced statistics on patient workload has the opportunity to plan for the most effective use of floor nurses.

In the ambulatory care area, medical information systems allow allied health personnel to expand upon the kinds of patient care services they provide. For example, in some experimental programs nurse practitioners and physician assistants provide primary care to patients by referring to computer protocols organized according to specific problems. Studies have indicated that physician assistants using protocols that explicitly define medical treatments provide care equivalent in quality to that of physicians in the traditional system (21,28).

A study at El Camino Hospital provides the only available data on how medical information systems affect the allocation of health professionals' time (7). An activity analysis of nursing time before and after implementation of TMIS found that:

- Time and effort allocated to clerical activities decreased across all units, from 4 percent in the coronary care unit to 47 percent in surgical units;

- The availability of information made reporting easier and less time consuming across all units;
- Time spent in direct patient care activities increased on some services (medical and intensive care) and decreased on others (surgical, orthopedic, pediatric, and coronary care).

The data show, as expected, a reduction of clerical activities. They are, however, inconsistent regarding the productivity of nursing staff in activities related to patient care. * Nurses on surgical units, for example, experienced the greatest reduction in clerical time, but they also spent less time in direct care of patients, The activity analysis at El Camino Hospital resulted in the reallocation and, in many cases, reduction of nursing staff. However, further evaluations of changes in staff productivity seem warranted.

HEALTH DATA SYSTEMS

Medical information systems could supply health data systems with accurate, easily accessible data. If standard classifications and codes were used and if all data sent to health data systems were already in computerized form, these organizations would be likely to realize substantial cost savings. Many health data systems aggregate data on national or regional levels and could thus take advantage only of widespread medical information systems.

Health data systems are collections of data organized for a variety of purposes, including reimbursement of health services, utilization review, and quality of care assurance, as well as planning, monitoring, and evaluating medical care services. Many health data systems obtain needed data from the hospital medical record. After a patient is discharged from an inpatient facility, data are abstracted from the medical record and placed on multiple forms for different purposes. The same or similar abstracted data may be used for reports to a Professional Standards Review Organization (PSRO), third-party payer claims, internal medical care audits, and institutional management reports. In an ambulatory care setting, data abstracted from the patient record may likewise be duplicated, although fewer health data systems collect ambulatory data.

The current method of abstracting data involves problems of quality as well as duplication. Error is possible each time data are transcribed to a different summary form. In addition, errors in coding can take place during the abstracting process. Patients' diagnoses and other data entered by medical providers into the medical record in words are placed by trained clerks into codes based on the international classification of diseases. This process involves interpretation of established rules as well as skill and care on the part of the clerk.

Medical information systems could provide health data systems with more accurate data in a more accessible form than is presently available. Once data are computerized, they are permanently available. Unnecessary duplication of data collection, with its attendant cost and error, could be avoided.

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* In addition to the implementation of TMIS, changes in staffing patterns and other variables may have contributed to the redistribution of nursing activities.

Medical information systems could, for example, supply patient discharge summaries to hospital discharge abstracting services like the Professional Activity Study (PAS) or for quality assurance programs like Professional Standards Review Organizations (PSROs). If data are automatically coded as they are entered into the system by medical care personnel, computer-produced abstracts would reduce both transcription and coding errors. In addition, medical information systems could efficiently provide necessary information for payment programs such as Medicare and Medicaid. With a computer system, these payment programs would be billed only for services actually rendered.

The usefulness of medical information systems for health data systems largely depends upon the extent to which patient data are entered into the computer record and the extent to which the computerized data are structured or coded. A system such as TMIS does not computerize large parts of the patient record, and some of the computerized data (for example, dictated radiology reports) are not structured. This kind of system is less useful for health data systems than a computer system like COSTAR, in which almost all patient data are entered and coded in the computer record. In PROMIS, all data are entered, structured, and linked to a specific problem of the patient. PROMIS can thus easily retrieve all data. Health data systems, however, usually aggregate by codes based on diagnosis and procedure rather than by "problem." Some information in the PROMIS data base may not be directly transferable to aggregate data systems. However, the edition of the international classification of diseases now being developed (lCDA-9CM) includes classifications for problems, and health data systems will be using the new classification scheme in the near future.

Computer produced abstracts can be sent to health data systems on paper forms or on computer tape. Health data systems would likely realize substantial cost savings if the data they receive were already in computerized form. However, these potential cost savings would occur only if medical information systems were widely used, standardized, and coordinated with health data systems. For example, only one of 2,000 hospitals that belong to PAS puts its discharge information on computer tape. To enter this information into its computer, PAS must process the data just as if they had been received on the manual forms.

Computer systems that capture some basic patient information for use in internal utilization review are commercially available, but no medical information system is coordinated with a health data system at this time.

PLANNING AND RESEARCH

Medical information systems could provide planners and medical researchers with data that are not available from existing health data systems. The computer systems store a data base that permits detailed analysis. If medical information systems with compatible data bases using standard definitions were widely adopted, they could be used to plan medical services, to evaluate the cost and efficacy of medical care, and to conduct clinical and epidemiological research.

The expense of obtaining data on patients limits the information available in most health data systems. The specificity necessary for some kinds of research may be lost when discrete events or diagnoses are grouped into classification codes. Electronic data banks generated by medical information systems such as PROMIS and COSTAR could make large amounts of disaggregated data available to authorized planners and researchers. Because the data are structured, patient-oriented, and accessible, they can be manipulated in an enormous number of ways.

Resource Allocation

Existing data are often inadequate to allow policy makers and planners to reach informed decisions about resource allocation. For example, little data exist about the the efficacy of medical treatments or the frequency and costs of complaints or problems that bring people to doctors. Medical information systems have the capacity to identify costs of medical services as they are provided and to relate these costs to patients' diagnoses and problems. In PROMIS, for instance, a charge is associated with every discrete unit of service, and the costs and effectiveness of medical treatment can be evaluated. Using medical information systems, costs for the treatment of a particular problem could be compared in various geographic regions, different kinds of medical care settings, or types of medical providers. Comparing one method of treatment with other modes can aid in determining efficacy. The availability of such data would support decisions about the allocation of facilities, manpower, and other medical care resources.

Institutional Planning

Presently, managers of medical care institutions use statistics based on events or activities, such as number of days in intensive care or number of electrocardiograms provided, rather than measures of productivity, efficiency, and effectiveness. Medical information systems can help to optimize the allocation of staff by supplying data on the amount of time spent by staff members on different kinds of services (41). Medical information systems can help administrators predict needs for new personnel, facilities, and supplies by providing data about the demographic and geographic distributions of individual patients being served, the kinds of problems they present, and the types of services utilized, with measures of changes in these distributions over time. Such information can now be obtained only through special studies at considerable expense.

Research

Both epidemiological and clinical research could benefit from computerized medical records that include patients' demographic characteristics and diagnostic information. Epidemiological research studies the frequency, distribution, population selectivity, and determinants of all cases of a particular disease or condition in a defined population. Clinical research experimentally tests hypotheses about diagnosis or treatment in groups of patients.

For studies in which similar groups of patients must be matched, for example, the computer could identify control groups with appropriate characteristics. Automatic search of the extensive electronic data base would simplify retrieval of outcome data or any other variables, and the computer could test for statistically significant correlations. Followup on patients participating in prospective studies would be expedited by continually updated information on addresses maintained in the medical information systems.

Major disease patterns in this country have shifted from infectious toward chronic conditions. Because chronic diseases have such long duration, gathering valid data about the histories of patients with such diseases has been virtually impossible. Computer-stored data banks offer the best prospect for learning their natural histories. The use of a computerized data bank for such research has been demonstrated in an experimental program at Stanford University (18). A computer stores data on all visits of patients being treated for arthritis or related chronic diseases. With this extensive data base, researchers have conducted statistical analyses, developed experienced-based data for clinical teaching, and advised clinicians on the management of individual patients. Eventually, new interventions could be tested against accumulated clinical experience to determine the most efficacious modes of treatment.

The usefulness of medical information systems for research, however, is subject to several constraints. In most epidemiological studies, valid statistical inferences can be drawn only if the population base (denominator figure) is known. Thus medical information systems that maintain data about all people in a given locality are most valuable for epidemiological research. Some studies also require data comparable over long periods of time, that is, trend data. Because only a few medical information systems are now operating, a historical data base will not be attained for many years. Moreover, the utility of medical information systems will be determined in part by the ability of clinicians to anticipate the "right" information for tomorrow's research. On the one hand, it is possible that computerizing all recorded information may not be valuable and economical. On the other, even systems like PROMIS, in which all recorded information is stored in the computer, may fail to include data crucial for future research.

CONFIDENTIALITY OF PATIENT RECORDS

The confidentiality of sensitize medical data could be violated if computer files were infiltrated. Today *computer records are more* secure than ***manual records. However, medical information systems are not widespread, and a potential problem does exist.***

Medical information systems make large quantities of personal medical information immediately accessible. The possibility of misusing computerized data has prompted concern (33). Medical data, especially psychological and social data, can be damaging to an individual when available outside the clinical context. Computer files could be infiltrated and lists of people with certain medical and social characteristics compiled. Such possible abuse presents complex legal problems seldom encountered with manual records. Unauthorized access to an individual's manual record is possible, but sorting records according to diagnostic, social, and other criteria is difficult.

Considerable effort has gone into creating procedures to safeguard the confidentiality of computerized medical records without denying easy access to authorized users. At present, each organization using a computer system has had to develop its own security precautions. These safeguards on computerized records include such measures as having key-lock terminals, plastic identification cards, passwords, or other identification codes (38). Codes identify users and permit them access to only those parts of the medical record necessary for carrying out their duties. Entries are similarly circumscribed.

No matter how sophisticated or complicated, mechanical security measures cannot ensure the complete confidentiality of medical records. At best, unauthorized access to computer files can be made time consuming and costly. At the same time, elaborate security systems may hinder authorized users from obtaining needed information and substantially raise the initial cost of the computer system.

A prime factor in securing the confidentiality of medical records may be adherence to professional codes of ethics by all those who work directly with patient records, automated or manual (11). Medical professionals are bound by their ethical codes not to disclose patient information. In some States, breaches of confidentiality constitute grounds for revocation of license. Similar ethical codes could be extended to nonmedical professionals, especially data processing personnel, who have access to computerized patient files (51).

Confidentiality can also be violated after the routine release of patient data to organizations outside the medical care institution. The Privacy Protection Study Commission, established by the Privacy Act of 1974, considered possible problems associated with the release of data about individuals. Its report recognized legitimate use of these data for research, auditing, and evaluation, but recommended disclosing only data necessary for a specific purpose and limiting subsequent uses and disclosures (42).

Limited access to the medical record might be more feasible in a medical information system than in a manual system. For example, identification of patients could automatically be stripped before pertinent data are released. Computerized records, however, facilitate the availability of detailed data to third parties and thus could increase the potential for misuse.

In order to control use of information within an organization and release of identified data to third parties, a report sponsored by the National Bureau of Standards suggests that precise standards be promulgated before computer systems proliferate (56). The report found that "computerized health records are more securely kept and processed today than manual records" and that "instances of leakage or misuse almost always take place in manual files" (56). Medical information systems are not widespread, however, and the report concludes that the main problem is one of potential harm.

5.

FACTORS INFLUENCING ADOPTION AND USE

5.

FACTORS INFLUENCING ADOPTION AND USE

Many potential benefits of medical information systems depend on their widespread use. Several factors, such as acceptability, technical transferability, and cost, can inhibit or encourage their adoption. Acceptability to medical care providers is crucial. Early systems failed in large measure because medical care providers found them hard to use. In order to be feasible economically, medical information systems must be adaptable to the unique needs of different institutions. Developers are modifying systems to make them applicable to many sites, but even so, medical information systems are an expensive technology. A number of institutions, however, have reported overall cost savings. New developments in computer hardware and software are likely to reduce further the costs of medical information systems. Other factors, such as economic incentives and constraints, are difficult to predict, but will also be important.

ACCEPTABILITY TO MEDICAL CARE PROVIDERS

Experience wilh the three computer systems discussed in this report indicates that familiarity with a system encourages medical personnel to accept it. Providers who regularly use a *system support it more strongly than those who are only occasional users.*

Medical information systems require providers to change their patterns of behavior. They must, for example, learn an entirely new set of procedures for keeping records. Breaking with established, habitual routine is difficult and sometimes frustrating. Providers were alienated at first. Developers point out, however, that most medical information systems are carefully structured so as not to disrupt traditional patterns of clinical thinking and patient management. At HCHP, each specialty group decided the format and content of its department's encounter form. At El Camino Hospital, physicians worked closely with Technicon's programmers in designing both content and organization of display frames.

The developers of PROMIS, in contrast, have not structured the system according to the preferences of the medical professionals who use it. Rather than adjusting their system to practitioners, the developers of PROMIS insist that personnel adjust themselves to it. PROMIS requires users to follow its decision logic and accept its guidance. It breaks sharply with traditional practice, in which each physician adheres only to his own rules and standards. In PROMIS practitioners are required, for example, to give a reason for any action. Because PROMIS tries to en-

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sure complete and logical care, recordkeeping is structured more rigidly than in other computer systems. However, in it, like the other two systems, physicians can add information.

Attitudes of providers toward use varies. At El Camino Hospital, a substantial majority of the medical staff support TMIS (7). It is used by 78 percent of the physicians at the hospital. Rate of use, however, varies from one service to another. Eighty-eight percent of all surgeons and internists, but only 32 percent of staff psychiatrists, use TMIS. Physicians on the attending staff generally accepted TMIS, and their attitude toward it has grown increasingly positive over time. Physicians are particularly positive about the system's capabilities for research and education. Nurses at the hospital also express a high degree of satisfaction with the system. Their evaluations of TMIS are, in fact, usually more favorable than those of physicians.

A survey at the Harvard Community Health Plan found that **87** percent of providers, including both physicians and nurses, prefer COSTAR to a manual system (5). Ninety percent of the providers believe that records are more readily available in COSTAR than in a manual system. Eighty percent believe that the automated system is less time-consuming than a manual one.

PROMIS received a mixed reception on the single ward at the University of Vermont Hospital in which it was implemented from 1971 to 1975. In a 1975 vote on the gynecology service, all of the nurses and a majority of the house officers, who were primary users of the system, voted to keep it. However, attending physicians voted eight to six to discontinue its use.

Acceptability to providers was a major problem in early systems. For example, early systems often malfunctioned, and physicians were frequently called upon to help adjust display frames. Resistance on the part of physicians to new innovations tended to inhibit the use of computer technology for clinical applications. However, many physicians now graduating from medical schools have been exposed to computer technology. As clinical applications of computers become more available, these physicians can be expected to use them.

Developers stress that the issue most important for acceptance is whether the medical information system makes patient care easier to provide. Physicians and nurses will, in other words, use a medical information system if they believe the system will aid them in providing care. Conversely, the provider who sees no benefits for personal job performance in the system will not use it regardless of inducements.

Developers of systems also report that the transition to a computer system is facilitated when (5, 19):

- Providers have time to learn how to use the medical information system on demonstration models before complete implementation takes place.
- Members of various provider groups are enlisted as spokesmen for the computer system. Providers react more favorably to the advice and example of their own colleagues than to that of technicians.
- No claims are set forth for the systems that cannot be fulfilled during implemental ion.

Undoubtedly, other factors also influence degree of acceptance, and more research is needed.

TECHNICAL TRANSFERABILITY

Medical information systems will have a major impact on the provision of medical care only if they can be successfully transferred to many medical care institutions. Prototype systems have been proven technically feasible, but most have not yet been *made* adaptable to the *various conditions of different institutions.*

Institutions differ on such fundamental characteristics as size and complexity, types of services provided, kinds of data collected, how data are used, and populations served. Institutions may perform similar procedures differently. Requirements for reporting laboratory tests may vary by institution. Medical care providers may use different formats and nomenclature for reporting the same therapy or procedure and do not agree about the definitions of many medical terms (12). As a result of these differences in institutions' needs, medical information systems transferred to new institutions have had to be modified during implementation.

Only if medical information systems are generalizable to various settings can the benefits of a standardized data base be realized and systems be marketed economically (3). If each institution modifies nomenclature and codes for patient data to accommodate individual needs, data cannot be used for planning and research. Modifying a medical information system for each institution is more costly than initially designing a system that many institutions can use. One study, based on statistical projections, concluded that if a system is to be used in 10 or more institutions, a "flexible" system, although initially expensive, is less costly than repeatedly modifying a more rigid prototype (57). Developers of COSTAR, TM IS, and PROMIS are working to make these systems more easily adaptable to various kinds of institutions.

The Laboratory of Computer Science at Massachusetts General Hospital and a group at George Washington University have worked together to develop a model ambulatory care system, based on COSTAR, that can be applied to many different practices. The new system is modular; it allows the basic capabilities of medical records, billing, registration, scheduling, and generating reports to be combined in various ways for different ambulatory care sites with minimal programing. Each practice will choose which modules to include in its system. For example, a practice could initially choose not to include the report scheduling module, but could add it to the system later.

The medical records module is the key component of the system. Each practice may design its own encounter forms, define much of the format, and choose the coded options it wants to include. Any additional coding schemes chosen by the practice will be introduced into the uniform COSTAR coding scheme to provide a standardized medical data base. If special programs, for example, for audit and peer review, were added to the system in the future, they could be easily transferred because all users will have the same file structure and programing language.

TMIS is already installed in six hospitals, including research and teaching institutions. In addition, activity is underway to make TMIS available to hospitals in modular form. The business office subsystem of TMIS can already be purchased separately. Although the basic system would still include computerized patient records, such capabilities as reporting results from the laboratory and radiology departments and plans for nursing care, could be excluded. These functions would be available as options that could be added to the core system at any time elected by user institutions.

The PROMIS Laboratory is redesigning hardware and software to make PROMIS transferable to locations of various sizes and financial resources. The system will be available in multiples of a small-scale unit called a "node." Each node consists of a minicomputer that supports from two terminals to between 30 and 60 terminals. A group practice may require only one or two nodes. In a hospital, many nodes can be joined to support hundreds of terminals. The PROMIS Laboratory has also developed a high-level computer language, PROMIS Programing Language (PPL), for any reprogramming that institutions might require and for keeping content of the system current (47).

In all of these approaches, developers are working to develop a system with a core that is applicable to many sites. Such a design would also allow purchasing institutions to make changes in display formats in order to meet special needs.

COST

Medical information systems are an expensive technology. However, a majority of institutions using medical information systems have reported considerable cost savings, particularly in labor expenses. Moreover, costs of computing hardware and thus the costs of medical information systems are expected to decrease.

Medical Information Systems in Hospitals

Operating costs for a hospital-based medical information system range from $4 to $9 per patient day or from 4 percent to 7 percent of the total hospital operating budget (2, 14). Technicon is marketing their system for $4 to $8 per patient day. PROMIS is still being developed. However, the PROMIS Laboratory estimates its costs will be in line with those of other medical information systems (35).

Cost depends upon the system, capabilities utilized, service arrangement with the vendor, and size of the institution. A 200-bed hospital, for example, may have expenses of $10 per patient day, while a 1,200-bed hospital, only $6 per patient day. Factors unique to the institution, such as patient mix (more intense care generates more activity to record and process), number of terminals desired, and degree of customization, further determine operating costs.

Operating costs for a medical information system are included with other operating expenses of an institution for the purpose of third-party reimbursement. No hospital reported any difficulty in obtaining third-party reimbursement for its medical information system (2).

Startup costs vary widely because many financial arrangements between hospitals and vendors are possible (2). Hospitals can lease or lease-purchase equipment and pay for an agreed upon list of services on a monthly basis. Computer hardware can be installed onsite, or the hospital can share the services of a central computer facility. Hardware and software can also be purchased under long-term financial arrangements. Either the institution or the vendor can employ technical support staff for the computer. One large hospital (over 500 beds), which purchased hardware and software, had initial costs of $2.5 million (2). Implementation costs in a medium-sized hospital, including physical installation and site development, for the Technicon system were reported to be about half-a-million dollars (24).

Installation of a medical information system may or may not be subject to Federal and State approval. Under Section 1122 of the 1972 Amendments to the Social Security Act, capital expenditures over $100,000 must be reviewed and approved by the Secretary of the Department of Health, Education, and Welfare. Thirty-five States have passed certificate-of-need laws that regulate expenditures by medical care facilities for new construction, equipment, and services. These laws require State review and approval for large capital expenditures, but the size of expenditure needing review varies from State to State.

In 1976, only three medical information systems had been reviewed by comprehensive health planning agencies, the precursors to health systems agencies (2). Not all systems require capital expenditures large enough for review, and relatively few medical information systems have been installed in hospitals. Two of these reviews were conducted under the authority of Section 1122, and one, in New Jersey, under certificate-of-need authority. The applications of all three hospitals were approved.

Savings in the costs of handling information is the primary justification for medical information systems. Baseline data on the costs of handling information in hospitals are sparse. Findings from two studies estimate that hospitals spend from 24 percent to 39 percent of their total operating budget on information processing (26, 44). About one-half of this cost is attributable to payroll expenses for personnel. Hospitals presently spend, on average, from 2 to 3 percent of their total operating budget for electronic data processing for accounting and management purposes (14).

Medical information systems cost about double the current average expenditure for the financial and management computer applications that they replace. Hospitals attribute savings in other areas to medical information systems: the elimination of printed forms, reductions in clerical, admissions, and nursing staff, and reduction in "lost charges"* (2). Because medical information systems could make possible improved cost accounting, reductions in length of patient stay, and increased productivity of medical care professionals, other savings may accrue.

Only one study has been reported that compares costs of an operating medical information system with costs that would have occurred if the hospital had used a manual medical record system during the same period (19). El Camino Hospital conducted this study. Under the terms of its initial contract, cost savings determined the hospital's payments to Technicon.

A large base of management data enabled El Camino Hospital to identify changes in costs, particularly costs of labor, throughout all departments of the hospital. Cost savings in labor were evaluated by three methods. First, potential savings in manpower time were measured by comparing time required for clerical tasks in a manual system and in TMIS. Next, actual nursing hours per patient day after implementation of TMIS were compared to nursing hours expected for the same time

* Because supplies and services are entered from areas of patient care into the medical information system at the time they are offered or provided and transferred electronically to the business office, chargeable items are not lost.

period with a manual system. Finally, trend analysis was used to compare El Camino's costs for nursing labor to those of other area hospitals providing similar services.

El Camino Hospital concluded that substantial cost savings in labor were realized from TMIS. Estimated savings attributed to the computer system ranged from $72,000 to $189,000 per month, and fixed operational cost of the system, as negotiated with the vendor, was $89,800 per month. Original projections anticipated that cost savings would not be shown before 4 years of operation, but were in fact demonstrated within 18 months of operation. Net benefits, after paying for the costs of the system, were estimated to range between $30,000 and $50,000 per month or between $3 and $5 per patient day. Labor savings, particularly in nursing, accounted for about 95 percent of the TMIS total cost savings. Certain revenue benefits, savings in materials, and avoidance of minor costs made up the other 5 percent.

As part of an evaluation contract with the National Center for Health Services Research, the Battelle Laboratory is conducting an independent evaluation of the economic impact of TMIS on El Camino Hospital. No data are presently available to verify the results of the El Camino Hospital Study.

Medical Information Systems for Ambulatory Care

A survey in 1974 of 18 ambulatory care sites operating medical information systems reported that costs ranged from $1 to $50 per patient year and from $0.50 to $14 per patient visit (23). If continuing development costs and depreciation on equipment are calculated with operating costs, total expenses range from $1 to $101 per patient year and $0.50 to $22 per patient visit. The total costs for operating COSTAR at HCHP, as reported in the survey, were $15 per patient year and $3 per patient visit.

In ambulatory care facilities as well as hospitals, installation costs for medical information systems depend on the kind of services to be acquired. Because most of the systems surveyed in 1974 were prototypes, costs of installation could not be separated from costs of development.

Twelve of the 18 surveyed sites credited their medical information systems with containing or reducing costs. Ten facilities cited savings in expenses for medical personnel. Eight sites estimated savings from more efficient financial and administrative management. However, the authors of the survey concluded that, while aggregate facility costs were reduced, there was no indication that medical information systems would have a direct effect on the cost of individual medical services. Further, no true cost savings in the ambulatory care facilities as a result of better utilization of personnel were identified.

Only one study in the literature reports costs of handling information in ambulatory care settings (40). The National Center for Health Services Research under contract to Bolt, Beranek, and Newman calculated costs according to time expended by personnel in data handling. The study suggested that a medical information system would lead to substantial savings if it stored all medical records and information for billing and also made data instantly available in many places. This study, which analyzed the clinic operated by an 11 physician group practice in Nashua, N. H., concluded that a minimum of $87,000 and a maximum of $142,000 in data processing and personnel salaries could be offset by an automated ambulatory medical record system. The study suggested that such a medium-sized group practice could support a capital investment for physical equipment in the range of $275,000 to $460,000.

Few medical information systems are located in such practices. Most operate in health maintenance organizations, outpatient departments of hospitals, large group practices, and federally subsidized clinics. The operating expenses of these large organizations for medical information systems are not representative of the costs that a smaller group practice might experience. The research group that has modified COSTAR estimates that the capital costs of their system will be about $85,000 at current prices for group practices of five to eight practitioners and about $125,000 to $200,000 for larger multispecialty group practices (6). Average monthly costs are projected within the range of current expenditures by group practices for billing activities alone, from $1,200 per month for small groups to $4,000 per month for larger group practices. If these cost projections hold up in the marketplace, such an automated record system would result in substantial cost savings by virtue of offsetting costs for information processing as reported in the Bolt, Beranek, and Newman study.

Cost Effectiveness

Although considerable cost savings due to medical information systems have been demonstrated at some institutions, no rigorous analysis of cost effectiveness has been conducted to date. A given technology is considered cost effective if it yields the desired outcome at the lowest cost unit (27). Analysis of cost effectiveness assumes that the desired outcome is known and can be measured. If a new technology is replacing a system already in existence, for example, a clinical laboratory system or a billing and accounting system, the desired outcome is well established. The new technology is accepted as cost effective if its costs are equal to or less than those of the system already installed.

Because medical information systems incorporate functions that did not exist in the manual medical record system, their cost effectiveness is more difficult to determine. The objectives of the old and the new systems are different. The timeliness of information transfer, the simultaneous availability of information at multiple locations, and the formation of an electronic medical data base are among benefits that were not possible with a manual system. Because medical information systems computerize necessary data, administrative costs of other organizations, such as abstracting services, PSROs, Medicare, and Medicaid may also be lowered. These possible savings are not typically considered when evaluating the potential of this technology.

Medical information systems have multiple objectives, then, and many of the new benefits cannot at present be directly measured. Current expenses for medical information systems may not represent true costs because most systems are still in a developmental stage. Developmental costs always are greater than subsequent routine operational costs (10). Also, methods for evaluating cost effectiveness have not been well developed. The National Center for Health Services Research, for example, has a contract with the University of Vermont to compare the effectiveness of PROMIS to a manual problem-oriented medical record used in the same clinical setting. The study group found that in order to conduct a valid comparison, the data entered in the manual records would have to be run through a computer.

In summary, although cost effectiveness has not been demonstrated, several studies have found that the introduction of medical information systems leads to considerable savings in labor expenses. In the past, wages of personnel have continually risen while the cost of computing hardware has decreased. Cost savings for institutions from the use of medical information systems can thus be expected to grow.

GENERAL FACTORS

Rate of use of medical information systems will depend on multiple factors applicable to any new technology. New developments in computing hardware and software, Federal policies, and economic incentives and constraints could facilitate or impede adoption. The effect of these factors on medical information systems is not now predicable.

Moving from development to availability of a new technology is a gradual process that proceeds through five phases: research, development, demonstration, industrial development, and finally, marketing (53). The general acceptance and use of a new technology usually lags considerably behind its availability. Estimates for the average time lag are from 10 to 15 years, but wide variation occurs (53). For example, the stethoscope was developed 113 years before its general use; defibrillators, 25 years; and electrocardiogram analysis by computer, 10 years (17).

The three medical information systems described in this report are at different stages in the transfer process. TMIS is being marketed and has already been installed in six hospitals. The research group developing an exportable COSTAR system estimates that several prototype systems will be operating by the end of 1977 (55). Staff at the PROMIS Laboratory estimate another 2 to 5 years of developmental activity before PROMIS will be available for marketing (35).

Medical information systems, in general, are still in the early stage of acceptance as an innovation in medical care. Factors applicable to any new technology may facilitate or impede the diffusion of medical information systems, but they have not yet come into force.

For a rapidly changing technology such as computers, advances in hardware could considerably speed the acceptance of medical information systems (l). Recently, microprocessors with the power and capacity of large computers at a fraction of the cost have become available. Further development could make low-cost computing feasible even for individual use. New memory technology has been developed that could remove all limitations on the volume of data stored. Small battery operated clipboard terminals, which are currently being designed, could allow providers to enter or obtain data from virtually any location.

On the other hand, institutions may defer investing in a system until the technology is more stable. Existing medical information systems are not expected to become obsolete in the near future, however, provided that current maintenance and development efforts continue (2).

Federal policy and economic factors will also impinge on the adoption of medical information systems. Managers of medical care institutions will consider general economic constraints and incentives in determining their need for a computer system. Government could encourage or discourage use through reimbursement policies and Federal and State regulations concerning capital expenditures. Direct Government intervention, as well, can be an effective tool influencing the diffusion process (36). Finally, market forces such as competition, profitability, and consumer demand will be important determinants of the time lag between the introduction and final adoption of a new technology (46).

6.

POLICY ISSUES AND ALTERNATIVES

6.

POLICY ISSUES AND ALTERNATIVES

A broad range of impacts accompanies the introduction of medical information systems into medical care institutions. Improved quality, coordination, and timeliness of data about patients have been documented. Some institutions have experienced cost savings, particularly in labor expenses. Other anticipated benefits, as well as possible disadvantages, of medical information systems have not yet been carefully studied. Two reasons are primarily responsible for this lack of evaluation. First, those medical information systems in use are, for the most part, prototypes. Second, those applications of medical information systems that may have the broadest impact on the medical care system are least developed. For example, few systems incorporate applications that support clinical decisionmaking and are capable of influencing the quality of medical care. None have been used to produce data on the cost and efficacy of medical care.

Careful consideration of Federal policy on medical information systems is nonetheless worthwhile at this stage of their development. The Federal Government supports basic research on such systems, but has few policy mechanisms to promote or guide the demonstration and diffusion of the technology. The issue of when and how the Federal Government should become involved in the development and use of medical information systems is important for several reasons.

- Existing systems vary in scope, cost, and impact on the medical care system. Consensus has not been reached about the defining characteristics of a medical information system.
- It is unlikely that a strong constituency will form in medical care institutions either supporting or opposing medical information systems. Unlike new diagnostic or therapeutic technologies that impact on special groups, medical information systems improve the use of medical services and affect all providers and patients in a medical care institution.
- Medical information systems are a costly technology. Initial costs for implementation may amount to millions of dollars; and operating expenses in a medium-sized hospital may exceed a million dollars annually.
- Medical information systems are currently installed in few institutions. Recent advances in computer technology, which will lower costs, could lead to rapid acquisition of a variety of systems. Unless the Federal Government formulates a policy toward medical information systems now, development and diffusion could proceed indiscriminately, making standardization impossible.

The range of policy alternatives that follows addresses how development of medical information systems can be directed for maximum benefit to the medical care system. The alternatives discussed are neither exhaustive nor mutually exclusive.

DEVELOPMENT AND DISSEMINATION

Presently, development of medical information systems is conducted by many investigators pursuing different approaches. The commercial computer industry is conducting limited marketing of medical information systems and continuing some research, Grants and contracts from the National Center for Health Services Research support research for some projects. Other Federal agencies (Veterans Administration, Indian Health Service of HEW, Department of Defense) are funding projects for Government-supported medical care facilities. A number of medical care facilities are using internal funding or funds from local government or foundations to develop systems for inhouse needs.

Alternative 1: Continue current research and development policies and allow dissemination of medical information systems to be determined by the open marketplace.

The first alternative available to the Federal Government is to allow the evolution of systems without direct intervention. The Federal Government could continue current levels of funding for research without attempting to influence the kinds of computer systems used in various medical care settings. This policy continues the pluralistic approach that now characterizes the delivery of medical care in the United States. Further, one school of economic thought presumes that in the open marketplace those computer systems benefiting the medical care institution will be adopted, while those that do not will compete unsuccessfully.

Continuation of present policy, however, could have several disadvantages. Because medical information systems support the organization of medical services, administrators of medical care facilities have been their primary consumers. The capabilities of medical information systems for improving institutional efficiency and supporting administrative functions are thus most marketable, as well as best developed, and systems limited to these functions could predominate.

A further risk is that industry will elect to market the technology without additional investments in research and development (R&D). Capabilities of medical information systems to improve and monitor the quality of medical care and to facilitate research and planning primarily benefit the patient and the medical care system as a whole, rather than the institution. Without further development, these potential benefits to the medical care system may be lost, although taxpayers would continue to support a large portion of institutional costs for computer systems through Medicare and Medicaid payments.

Continuation of present policy could also maintain a slow rate of dissemination for medical information systems. Except for the few institutions with the technical personnel, financial resources, and motivation to develop their own computer systems, medical care facilities would have the option of choosing only from among those systems available commercially. Because industry must recover R&D costs through market prices, institutions without large capital resources (primarily smaller facilities) might be unable to acquire a medical information system.

If Federal action influencing development and eventual use of medical information systems were considered desirable, several strategies could be pursued.

> **Alternative 2:** Establish a central clearinghouse to coordinate developmental projects and provide information to the public about medical information systems.

Conferences, or other forums, could ensure that technical innovations are shared and ideas exchanged. Various medical information systems could be classified and ranked by their capabilities. Guidelines could be developed for use by hospitals and other medical care facilities in selecting, implementing, and evaluating medical information systems.

Because diverse groups are developing medical information systems, representation by all sectors, including public, private nonprofit, and commercial, would be appropriate at these forums. Although the coordinating group need not be a governmental agency, several Federal agencies could perform this function. Since its establishment in 1969, the National Center for Health Services Research has had primary responsibility for medical information systems technology. It has convened a conference for investigators working on automated ambulatory medical records. The Bureau of Health Planning and Resource Development (BHPRD) provides technical assistance to areawide health systems agencies (HSAs), which have regulatory authority over capital investments by medical care facilities. BHPRD currently is funding a study comparing automated hospital information systems that are available commercially. Other offices in the Department of Health, Education, and Welfare might also perform the clearinghouse function. For example in the National Institutes of Health, the Lister Hill National Center for Biomedical Communications has a mandate to develop networks and information systems for improving health education, medical research, and the delivery of medical services.

Having a central organization coordinate information about medical information systems would demonstrate the Federal Government's interest in these computer systems. By increasing public awareness, it might promote adoption of medical information systems. If systems were carefully classified by capability and relative value, administrators would be more able to act as prudent buyers. Furthermore, an approach based on public information would not violate current policy of removing the Federal Government from the direct dissemination of new technologies. This approach, however, holds no incentives for developers to expand the capabilities of systems or for medical care facilities to purchase such systems.

> **Alternative 3:** Provide funding for evaluation of medical information systems in a number of different medical care facilities and locations to determine their effectiveness in terms of relative benefits and costs.

A number of questions regarding medical information systems remain unanswered. Because a medical information system in a medium-sized community hospital is the only one that has been evaluated in depth, * studies of costs and impacts in

● The Technicon Medical Information System at El Camino Hospital was evaluated in an in-house study and by an independent contractor, the Battelle Laboratories.

other kinds of medical care delivery settings are needed. For example, smaller institutions would not necessarily realize the same economies from medical information systems as large facilities. Existing systems have differing capabilities, but it is not known which systems would have the greatest impact in different kinds of settings. The cost effectiveness of systems designed for use in small groups or even solo practices has not been carefully studied.

Priorities on the kinds of medical care facilities that might use medical information systems have not been established. On one hand, priority might be given to teaching hospitals so that detailed data about less common conditions can be made available for research. If, on the other hand, priority went to small hospitals, community physicians could benefit from the capabilities of medical information systems for continuing education and quality assurance.

Funding the evaluation of a sufficient number of medical information systems would provide the necessary information on which policy makers could base decisions. In addition, placement of medical information systems in various kinds of facilities and in different parts of the country would enhance their visibility. Having a number of systems operational could itself spur further adoption.

The National Center for Health Services Research has authority to fund such evaluation projects through grants and contracts to investigators in the field. Medical information systems in institutions operated by the Government could be funded directly by the responsible Federal agencies. No new legislation would be required to implement this approach, although additional funding may be needed.

Alternative 4: Ensure the availability of medical information systems with specified capabilities and applications by contracting for their development.

Additional development of medical information systems is necessary to achieve the full range of anticipated benefits described in this report. To speed development of systems with desired characteristics, the Federal Government could conduct a targeted research and development program. Government could contract directly for the development of medical information systems with specified capabilities and applications.

Under this approach, Government would absorb the larger portion of R&D costs, while private industry would be encouraged to invest its money in marketing the systems and reducing their costs. Targeted development would eliminate duplication of efforts and would ensure the availability of broad-based systems with full capabilities. Without more extensive information than is presently available, however, specifications for such development would be difficult to formulate. Supporting research by grant funds tends to encourage new ideas and approaches. Grants may still be the most appropriate mechanism for developing medical information systems.

Contracting with industry for the development of needed technologies is a common procedure for Federal agencies such as the Department of Defense and the National Aeronautics and Space Administration. The National Center for Health Services Research, however, does not currently have the authority to contract for the development of new medical technologies. Contracts can be used only to obtain specifications for the operation of an existing technology. Enabling legislation limited NCHSR to support of research, evaluation, and demonstration projects. Modification of NCHSR Legislation would therefore be required to implement this alternative.

Alternative 5: Provide incentives for medical care facilities to adopt medical information systems that improve the quality of patient care and support research and planning.

Even after medical information systems with full capabilities have been developed and tested in the field, several factors could discourage their purchase. Medical information systems must compete with other technologies for the financial resources of medical care facilities. They compete directly with computer systems designed solely for administrative and billing purposes. The functions of these subsystems would be subsumed by medical information systems, but management and financial systems are well established, have proven capabilities, and can usually be purchased at lower cost than medical information systems.

Current payment methods encourage the adoption of technologies that produce revenues for the institution. Thus, facilities might invest in new diagnostic and therapeutic technologies instead of medical information systems. Hospitals can itemize patients' bills for tests and procedures, but not for the services of medical information systems, which are included as a part of a daily inpatient rate. Furthermore, the practice of public programs paying on the basis of "reasonable costs" does not create a strong incentive for institutions to adopt cost-saving technologies, although medical information systems can reduce some institutional expenses.

The Federal Government could promote the dissemination of medical information systems through appropriate incentives and sanctions for medical care institutions. Two possible mechanisms could be employed: regulatory authority over capital expenditures and direct subsidy.

Under section 1122 authority of the 1972 Amendments of the Social Security Act and, in many States, under certificate-of-need legislative authority, local health systems agencies (HSAs) review and either approve or deny hospital applications for capital expenditures over $100,000. Under Federal guidelines, these HSAs could deny applications for computer systems that do not meet specified capabilities. The Bureau of Health Planning and Resource Development (BHPRD), which supplies HSAs with technical advice, could issue guidelines to define acceptable computer applications.

The Federal Government could also directly subsidize the purchase of medical information systems. Grants, loans, loan guarantees, or interest subsidies could be given to institutions purchasing approved computer systems. Such financial assistance could be a strong incentive for implementation of computer systems by medical care facilities otherwise lacking sufficient capital.

Existing legislative authority allows NCHSR to make grants available to nonprofit institutions for the demonstration of medical care technologies. Health systems agencies could also give grants from their area health services development funds. State health planning and development agencies could make loans, loan guarantees, and interest subsidies available from health resources development funds. This latter alternative would require amending legislation by Congress. Health resources development funds are now restricted to modernization projects of facilities and exclude the purchase of new equipment such as medical information systems.

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CONTROL AND STANDARDIZATION

Beyond the development and dissemination of medical information systems, initiatives by the Federal Government could ensure uniform impact of the computer systems. Controls on medical knowledge incorporated into medical information systems would maintain the quality and credibility of the computer systems. Standardized patient data bases would permit PSROs, planners, and researchers to use medical information systems. Issuance of standards could protect the confidentiality of computerized patient records. In each case, the professional groups affected should be consulted. The following alternatives address these issues of standardization.

Alternative 6: Charge a central organization with authority for developing, validating, and maintaining the content of medical knowledge within medical information systems.

Without controls on the entry of medical knowledge into medical information systems, therapies, drugs, or tests of unproven efficacy could be incorporated as guidelines for physicians in computer programs. A central organization could control and accredit the content and distribution of medical knowledge frames, All systems would thus contain carefully researched medical information of uniform quality. Having a central organization distribute medical content frames would also ensure the dissemination of new medical knowledge as it becomes available.

The National Library of Medicine in the National Institutes of Health has recognized expertise in the area of medical information. It, or a newly established organization, could be funded and staffed to perform this function.

Alternative 7: Develop standardized medical data bases, including nomenclature, terms, definitions, classifications, and codes, for use in medical information systems.

A standardized data base would permit the coordination of medical information systems with health data systems. If standardized, data from different medical care settings and geographic areas would be comparable and could be used for research and planning. More uniform specifications of data base content would expedite the transfer of the technology by enabling the production of multiple copies of systems and fewer "custom-built" applications, Similar research and development in the standardization of programing languages also would be required so that software could readily be exchanged among systems.

The National Center for Health Statistics (NCHS) is the Federal agency charged with providing general-purpose health statistics on the Nation's population. Many activities of NCHS bear upon comparability and definitions of medical data. The U.S. National Committee on Vital and Health Statistics is an independent panel of experts who serve in an advisory capacity to the Secretary of DHEW. The National Committee has recommended minimum uniform data sets for different medical care settings and is now conducting a review of the classification of diseases. These groups, or others, could direct development of standardized medical data bases.

Alternative 8: Establish guidelines for precise standards to protect confidentiality of patient data within an institution and release of identified data to third parties.

Unauthorized access to patient data within an institution is a potential danger of medical information systems. Standardized security precautions and careful delineation of staff responsibilities would minimize this risk. Computerized patient files also make detailed data available to outside organizations. Laws and policies that define limits on data sharing could be developed as well as mechanisms to police these boundaries. The National Bureau of Standards in the Department of Commerce, which has recently supported a detailed study on computers and health records, is one agency that could develop standards and recommendations to protect the confidentiality of patient data.

BIBLIOGRAPHY

BIBLIOGRAPHY

1. American Federation of Information Processing Societies. *Proceedings of 1977 National Computer Conference.* Montvale, N. J., 1977.
2. "Automated Hospital Information Systems. " Systemedics, Inc., report prepared for Health Resources Administration, U.S. Department of Health, Education, and Welfare. Princeton, N. J., April 1976 (Reissued October 1976).
3. Baker, R, L.; and Spencer, W. A., "Considerations for Evaluating Transferable Automated Information Systems. " *Computers and Biomedical Research* 7: 249-65, 1974.
4. Ball, M., ed. *How to Select a Computerized Hospital information System.* Basel: S. Karger, 1973.
5. Barnett, G. O., "Computer-Stored Ambulatory Record (COSTAR). " NCHSR Research Digest Series, DHEW Pub. No. (HRA) 76-3145, 1976.
6. Barnett, G. O., Laboratory of Computer Science, Massachusetts General Hospital, Boston, Mass., letter of June 6, 1977.
7. 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. " Battelle Laboratories, report to National Center for Health Services Research, U.S. Department of Health, Education, and Welfare. Columbus, Ohio, 1975.
8. Baruch, J. K., "The Generalized Medical Information Facility." *Inquiry* 5: 17-23, 1968.
9. Brunjes, S. D., "Problems at the Interface of Computers in Medicine." *Advanced Medical Systems: Issues and Challenges.* Edited by C.D. Flagle. New York: Stratton Intercontinental Medical Book Corporation, 1975.
10. Cohen, M. F., "General Requirements." *Hospital Computer Systems.* Edited by M.F. Cohen. New York: Wiley Biomedical-Health Publications, 1974.
11. Curran, W. J.; Stearns, B.; and Kaplan, H., "Privacy, Confidentiality and Other Legal Considerations in the Establishment of Centralized Health-Data Systems." *New England Journal of Medicine* 281:241-48, 1969.
12. Davis, L. S., "Data Processing Facilities," *Hospital Computer Systems.* Edited by M.F. Cohen. New York: Wiley Biomedical-Health Publications, 1974.
13. DeLand, E. C.; and Waxman, B. D., "Review of Hospital Information Systems. " *Hospital Information Systems.* Edited by G.A. Bekey and M.D. Schwartz. New York: Marcel Dekker, Inc., 1972.
14. Dorn, P. H., "Funding the Operation. " *Datamation* (September 1975), 51.
15. DuBois, R., National Center for Health Services Research, U.S. Department of Health, Education, and Welfare, telephone conversation of August 1976.
16. Federal Council for Science and Technology, Panel on Health Services. *Final Report of Committee on Automation Opportunities in the Service Areas.* May 1972.
17. Fox, C. R., "Administration of Health Computing," paper presented at the Health Computing Careers Symposium, Dallas, Tex., June 1977.
18. Fries, J. F., "Time-Oriented Patient Records and a Computer Databank." *Journal of American Medical Association* 222:1536-42, 1972.
19. Gall, J. E.; Norwood, D. D.; Cook, M.; Fleming, J. J.; Rydell, R.; and Watson, R.R. "Demonstration and Evaluation of a Total Hospital Information System. " El Camino Hospital report to National Center for Health Services Research, U.S. Department of Health, Education, and Welfare, December 1975.

20. Giebink, G. A.; and Hurst, L. L., *Computer Projects in Health Care.* Ann Arbor: Health Administration Press, 1975.

21, Grimm, R. H.; Shimoni, K.; Harlan, W. R.; and Estes, E. H., "Evaluation of Patient-Care Protocol Use by Various Providers." New *England Journal of Medicine* 292:507-11, 1975.

22. Hall, P., "Information Science, The Patient and the Medical Record. " *Information Processing of Medical Records.* Edited by J. Anderson and J.M. Forsythe. London: North-Holland Publishing Company, 1970.

23. Henley, R. R.; and Wiederhold, G., "An Analysis of Automated Ambulatory Medical Records Systems: Findings." AARMS Study Group, University of California, San Francisco, June 1975.

24. Hicks, I., Technicon Corporation, Mountain View, Calif., letter of June 13,1977.

25. Holder, A. R., "The Importance of Medical Records." *Journal of American Medical Association* 228:118-19, *1974.*

26. Jydstrup, R. A.; and Gross, M. J., "Cost of Information Handling in Hospitals. " *Health Services Research 1: 235-71,* 1966.

27. Klarman, H. E., "Application of Cost-Benefit Analysis to Health Systems Technology." *Journal of Occupational Medicine 16:172-136, 1974.*

28. Komaroff, A. L.; Flatley, M.; Browne, C.; Sherman, H.; Fineberg, S. E.; and Knopp, R. H., "Quality, Efficiency, and Cost of a Physician-Assistant-Protocol System of Management of Diabetes and Hypertension. " *Diabetes* 25:297-306, *1976.*

29. Louisell, H.; and Williams, D., *Medical Malpractice. New* York: Matthew Bender & Co., Inc., *1960.*

30. McDonald, C.J., "Protocol-Based Computer Reminders, The Quality of Care and the Non-Perfectibility of Man." New England *Journal of Medicine* 295:1351-55,1976.

31. McDonald, C.J., "Use of a Computer to Detect and Respond to Clinical Events: Its Effect on Clinician Behavior." *Annals of Internal Medicine.* 84:162-67, *1976.*

32. McDonald, C.J., Regenstrief Health Center, Indianapolis, Ind., letter of July 8, 1977.

33. McNamara, J.J., "Legal Aspects of Computerized Medical Records. " *Journal* of *American Medical Association* 205:153-54, *1968.*

34. Matte, P. J., "Medicolegal Aspects of Automated Medical Records.." *Legal Medical Annual, 324-49,* 1974.

35. Miller, D., PROMIS Laboratory, Burlington, Vt., interview of June 1976.

36. "The NASA Role in Major Areas of Human Concern: Health Care." Denver Research Institute, report prepared for Technology Utilization Office, NASA, February 1974.

37. Ontario Department of Health. "Health Care Delivery Systems, Role of Computers in the Health Field." Suppl. 9, 1970.

38. Opp, M., "The Confidentiality Dilemma." *Modern Healthcare* (May 1975) 49-54.

39. Pengov, R. E., Ohio State University, College of Medicine, Columbus, Ohio, interview of July *29, 1977.*

40. Pickett, R. M.; Massey, L. D.; Miller, D. C.; and Whitehead, S. F., "A Study of Information Commerce in an Ambulatory Clinic," Bolt, Beranek, and Newman, report for the National Center for Health Services Research, August 1975.

41. Pollack, E. S.; Windle, C. D.; and Wurster, C. R., "Psychiatric Information Systems: An Historical Perspective." *Progress In Mental Health Information Systems.* Edited by J.L. Crawford; D.W. Morgan; and D.T. Gianturco. Cambridge, Mass.: Ballinger Publishing Co., 1974.

42. Privacy Protection Study Commission, *Personal Privacy* in *an Information Society.* Washington, D. C.; U.S. Government Printing Office, 1977.

43. Pryor, T. A.; Morgan, J. D.; Clark, S. J.; Miller, W. A.; and Warner, H. R., "HELP — A Computer System for Medical Decision Making." *Computer* (January 1975), 34-38.

44. Richart, R. H., "Evaluation of a Medical Data System," paper presented at the Conference on Medical Information Systems, San Francisco, Calif., *1970.*

45. Richart, R. H., "Evaluation of a Hospital Computer System." *Hospital Computer Systems.* Edited by M.F. Cohen. New York: Wiley Biomedical-Health Publications, 1974.
46. Sanders, D. H., *Computers and Management in a Changing Society.* New York: McGraw-Hill Book Company, 1974.
47. Schultz, J. R., "PROMIS: Problem-Oriented Medical Information System." January 1976. (Photocopy.)
48. Schwartz, W. B., "Medicine and the Computer, The Promise and Problems of Change." *New England Journal of Medicine* 283:1257-64, 1970.
49. Soghikian, K., "Preventive Health Maintenance Clinics." *Hospital Computer Systems.* Edited by M.F. Cohen. New York: Wiley Biomedical-Health Publications, 1974.
50. Spink, J., "Medication Errors in Hospitals." *Medical Trial Technique Quarterly* 21:271, 197s,
51. Springer, E. W., *Automated Medical Records and the Law.* Pittsburgh, Pa.: Health Law Center, 1971.
52. *State of Information Processing in the Health Care Industry.* Hospital Financial Management Association, 1976.
53. "Technology Transfer Process in Government, Industry and Health." Health Care Management Systems, Inc., La Jolla, Calif., October 1975. (Photocopy.)
54. Walton, P. L., "PROMIS: The Problem-Oriented Medical Information System—An Overview." Background Reading *Material: PROMIS,* Bureau of Health Services Research, Health Resources Administration, U.S. Department of Health, Education, and Welfare, Rockville, Md., 1973.
55. Waxman, B., National Center for Health Services Research, U.S. Department of Health, Education, and Welfare, interview of July 1976.
56. Westin, A. F., "Computers, Health Records, and Citizen Rights." National Bureau of Standards Monograph 157, U.S. Department of Commerce, December 1976.
57. Zimmerman, J., "Dissemination of Computer Applications Via a Multi-Environment Scheme (MESCH)." Biomedical Computer Laboratory, Mongraph No. 248, Washington University School of Medicine, St. Louis, Me., November 1974.

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